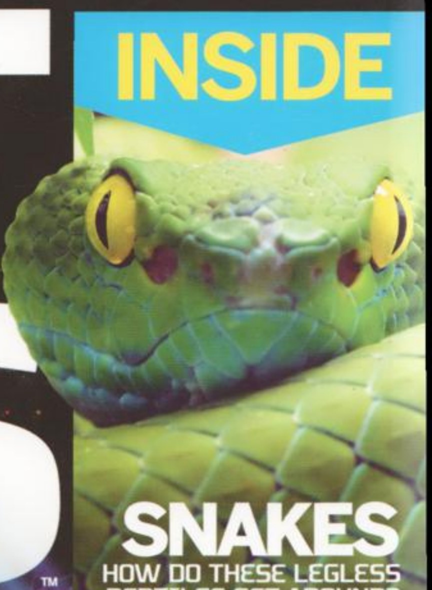
THE MAGAZINE THAT FEEDS MINDS

HOW IT WORKS™

SCIENCE · ENVIRONMENT · TECHNOLOGY · TRANSPORT · HISTORY · SPACE

INSIDE



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NEXT-GEN ROBOTICS
How state-of-the-art robots are replacing humans

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Inside the new breed of Android smartphone

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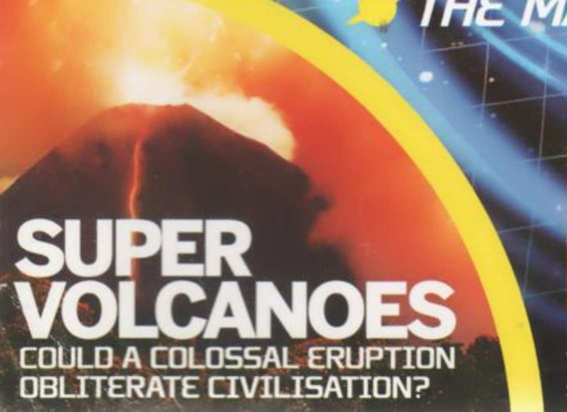
- THE POWER TO CONSUME THE MILKY WAY
- THE HEART OF VIRTUALLY EVERY GALAXY
- THE MASS OF SEVERAL BILLION SUNS



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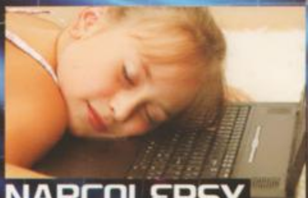

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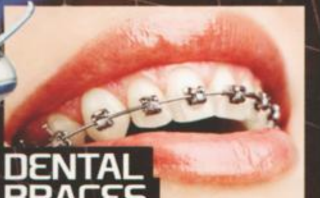
Discover the future of super-efficient air travel



DENTAL BRACES
How do these metal frames straighten crooked teeth?

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HOW IT WORKS

WELCOME

The magazine that feeds minds! **ISSUE 30**

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MEET THE EXPERTS

Find out more about the experts behind your favourite articles in this issue's edition of **How It Works...**

Vivienne Raper
Supervolcanoes

Geophysicist Vivienne explains the geography and danger of the sleeping giants with the potential to blow suddenly and wreak destruction across continents and even wipe out nations altogether.

James Baker
Next-gen robots

Robotics expert James, who built bots for cult TV show *Robot Wars*, recently returned to writing about all things AI, making him an obvious choice to scribe our tech feature on the automatons of the future.

Susie Kearley
Metabolism

Health and nutrition expert Susie writes on a diverse range of subjects from antioxidants to adrenaline. This issue she explains human metabolism as well as how the shoulder works.

Bridget McDermott
Roman villas

This issue our history writer Bridget reveals the construction of Ancient Rome's magnificent villas, exemplified by airy courtyards and intricate mosaics, some of which have survived to this day.

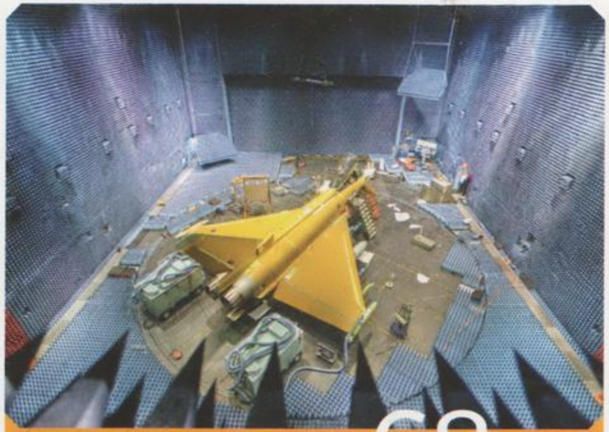
Nigel Watson
Early cinema sound

Nigel's film degree proved invaluable when writing his piece about how sound was introduced to the cinema on page 79. Take a look and discover the early use of recorded sound in talkies.

Richard Aucock
Camshafts

An authority on all things automotive, motoring writer Richard explains why timing and a car's camshaft work together to control the flow of fuel and air in an engine. He also covers boat rudders and snow tyres.

"FEED YOUR MIND!"



EDITOR'S PICK 68

This state-of-the-art chamber is used to test electromagnetic interference on jets. A separate soundproof room, dubbed the hush house, enables the likes of the Eurofighter Typhoon to be tested at full throttle without offending the ears of the locals.

THE SECTIONS EXPLAINED

The huge amount of info in each issue of **How It Works** is organised into these sections

THE MAGAZINE THAT FEEDS MINDS
HOW IT WORKS
INSIDE
SNAKES
SUPERMASSIVE BLACK HOLES
SUPER VOLCANOES

ENVIRONMENT
The splendour of the natural world explained

TRANSPORT
Be it road, rail, air or sea, you'll find out about it in the transport section

SCIENCE
Explaining the applications of science in the contemporary world around us

HISTORY
Your questions about how things worked in the past answered

TECHNOLOGY
The wonders of modern gadgetry and engineering explained

SPACE
From exploration of our solar system to deep-space adventures

HOW TO DECIPHER YOUR QR CODE...

This black and white matrix barcode is what's known as a QR code and in it we've concealed a random – but nonetheless intriguing – fact for you. To decode this message you'll need to download a QR code reader app on to your mobile phone. Then simply view the code through the camera screen and the secret message will appear.

With thanks How It Works would like to thank the following organisations for their help

london transport museum
sciencemuseum
MANCHESTER 1824
The University of Manchester
The Manchester Museum
National Museums Scotland
DK
NASA

Among the fascinating wonders of the universe, the black hole represents perhaps the epitome of space spectacles that really boggle the mind. From their unfathomable scale to their galaxy-gulping potential, these mysteries of the cosmos never cease to keep the curious among us wondering. How are they responsible for so much of the energy output in the universe, why do their super-strong gravitational fields prevent light escaping from within them, what is the event horizon, how can a singularity the size of a full stop contain the mass of a billion suns? This issue we reveal the awe not only of black holes but supermassive ones too – the kind that possess enough energy to create, power, consume and destroy galaxies.

Also this issue we explain the events that could occur were a supervolcano to erupt tomorrow. While we know there are several lying dormant around the globe – one of which is beneath Yellowstone National Park – the likelihood of one going off in our lifetime is practically non-existent. However, learning about these natural time-bombs is integral to our understanding of the history of our planet as well as what could happen in the future. This one makes for sensational reading.

Enjoy the issue,

Helen

Helen Laidlaw
Editor

Meet the team...

Dave
Ed in Chief
Loads of features caught my attention this issue, including the future of robotic tech and how these machines are increasingly being used to do the jobs humans can't or won't.

Rob
Senior Staff Writer
I was surprised by the Dreamliner. At first glance it appears to be just another passenger jet, but scratch the surface and you'll find it represents the super-efficient future of commercial jet travel.

Jonny
Staff Writer
This month I had great fun writing about fire, supermassive black holes and the evolution of spacecraft, among other things. Issue 30 is most definitely one of my favourites to date.

Adam
Senior Sub Editor
Not sure what I felt most about supervolcanoes – awe or terror – but it sure makes for a gripping feature. I also enjoyed finding out about Nikola Tesla's achievements – he deserves a lot of respect.

HOW IT WORKS

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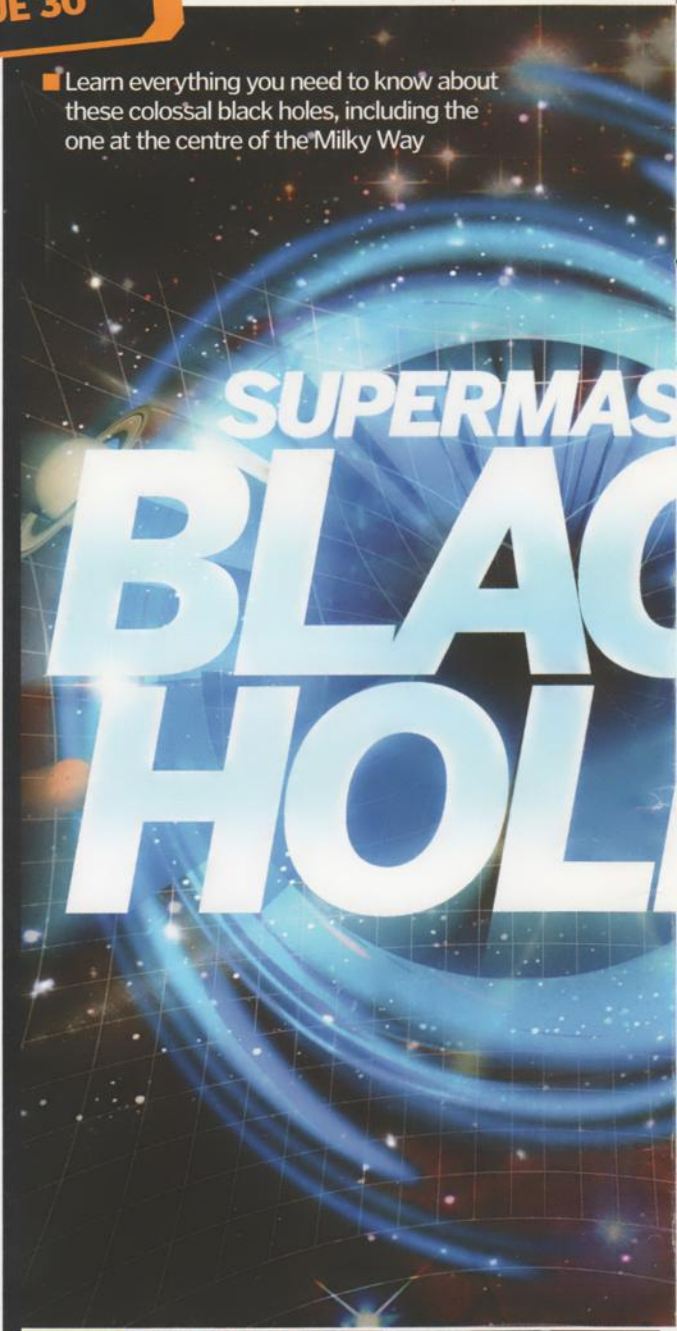

Learn everything you need to know about these colossal black holes, including the one at the centre of the Milky Way

Supervolcanoes
In this terrifying article, discover exactly what a mega eruption could mean for human civilisation

82 **Expert answers**
Scientists from the finest museums in the world answer your questions in this issue's jam-packed Brain dump

Caroline Warhurst
London Transport Museum
The information services manager at London Transport Museum, Caroline is here to answer all your transport-related questions this issue.

Louise Thomas
Science Museum
Louise previously worked as a freelance museum educator. She has an MA in Museum Studies, enjoys spaghetti bolognese and loves ten-pin bowling.

Kate Sherburn
The Manchester Museum
Kate works with the Zoology and Palaeontology collections at the Museum. She is particularly interested in aquatic biology, especially sharks.

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GLOBAL EYE NEWS

The most sensational news and pictures from around the world

Showcasing the incredible world we live in...

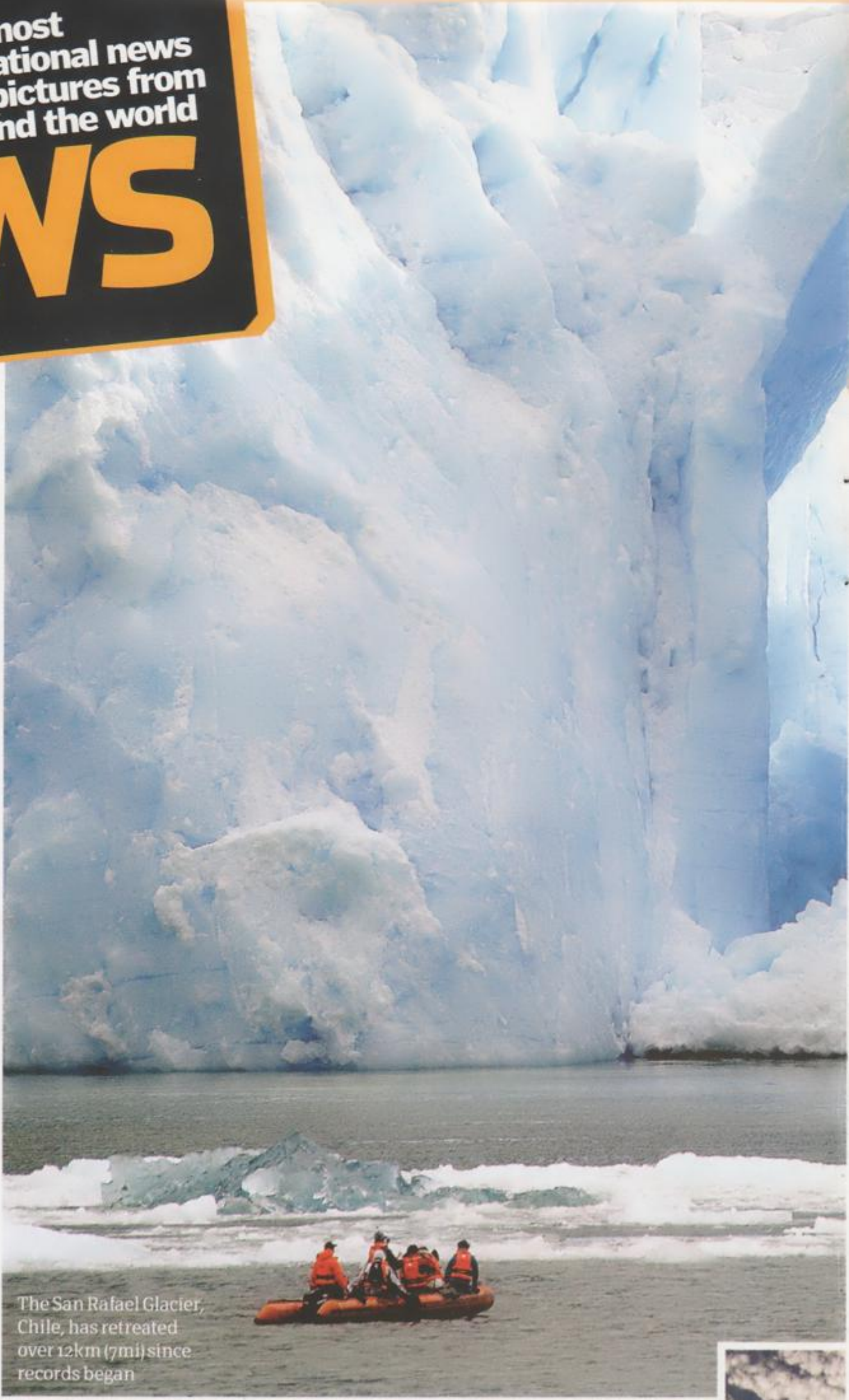
Vanishing glaciers shock scientists

Terrifying new research reveals the Patagonian Ice Fields – home to vast reserves of Earth's fresh water – are shrinking at an alarming rate

According to new research undertaken by the Centre for Ecosystem Research in Patagonia (CIEP) and Chile's Centre for Scientific Studies (CECS), 90 per cent of the region's glaciers are in retreat, sparking renewed efforts by scientists to completely understand their dynamics and how they are affected by climate change. The alarming figure is the result of a study of over 100 glaciers in Chile by the government, as well as national and international research teams.

Leading this research charge is Takane Matsumoto, a glaciologist at the CIEP, who is journeying once a year to the Northern Patagonian Ice Field to acquire information about this glacier region's temperature, humidity, precipitation and wind speed from numerous monitoring stations. Key to Matsumoto's enquiries are the effects of meltwater, charting how released water flows through the glacier and out into the surrounding environment. This research, it is hoped by Matsumoto, will help demonstrate how quickly the region's glaciers are disappearing and what potential effects that will have on local water resources.

About 75 per cent of the world's freshwater reserves are held in glaciers and ice sheets, with the 14,000-square-kilometre (5,405-square-mile) Patagonian Ice Fields ranked third in the world's largest, after Antarctica and Greenland. Interestingly, according to additional research released recently by glaciologist Neil Glasser of Aberystwyth University, UK, since 1870 the Northern Patagonian Ice Field has lost over 100 cubic kilometres (24 cubic miles) of ice and the Southern Patagonian Ice Field more than 500 cubic kilometres (120 cubic miles).



The San Rafael Glacier, Chile, has retreated over 12km (7mi) since records began

Meltwater scores caves and tunnels through a glacier – scientists are currently researching how this affects its speed of decay

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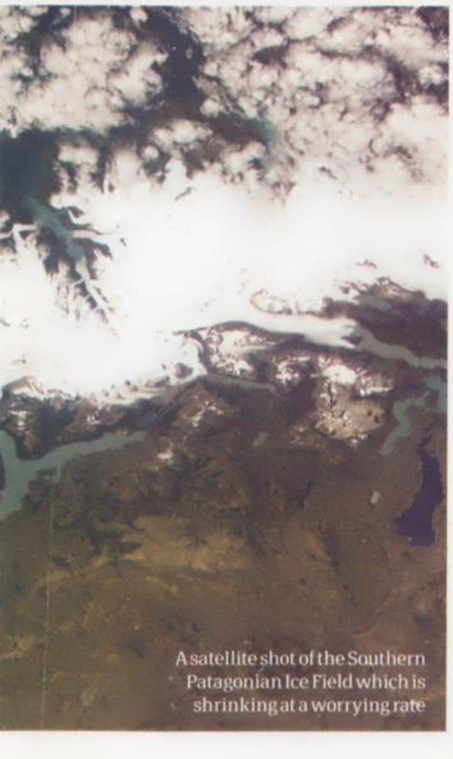
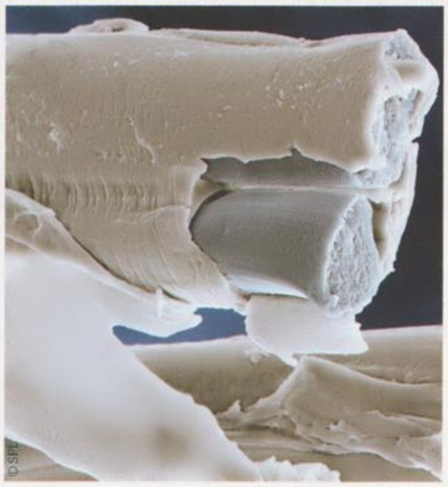


A satellite shot of the Southern Patagonian Ice Field which is shrinking at a worrying rate

© Dennis Jarvis

The scientists hope the breakthrough will allow super-strength silk to be produced on an industrial scale

Right: A silk fibre at 3,000x magnification. Silk is obtained from the cocoons of silkworm larvae



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Spider-Man silk engineered

Genetically modified silkworms produce super-strength silk with huge potential

A team of scientists from the University of Wyoming in the United States have managed to produce a new breed of silkworm capable of producing super-strong silk. It is hoped that the new material could eventually be produced on an industrial scale.

While weight-for-weight the silk produced by spiders is stronger than steel, they can only produce it in limited quantities. Silkworms, meanwhile, can create silk in much greater quantities for harvesting on a massive scale. The downside to silkworm silk, however, is its relatively weak structure, which has limited its applications to date.

Genetically modifying the silkworms by transplanting genes from spiders into the worms has enabled the realisation of a new type of 'Spider-Man' silk. The new fibres can offer a far greater array of applications, ranging from medical implants and ligaments, through to a greener substitute for toughened plastics.

Speaking on the publication of the research in the notable *PNAS* journal, Dr Christopher Holland from the University of Oxford said: "Essentially, what this paper has shown is that [the University of Wyoming team] are able to take a component of spider silk and make a silkworm spin it into a fibre alongside its own silk. They have also managed to show that this composite, which contains bits of spider silk and mainly the silkworms' own silk, has improved mechanical properties."

The DK quiz

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Dorling Kindersley has created a selection of super-fun quizzes in which you can test your brainpower. What's more, several have even been completed in collaboration with your favourite knowledge magazine. To take the **How It Works** quizzes, as well as a host of others expertly crafted by Dorling Kindersley, why not swing by **www.dkquiz.com** and put your grey matter to the test?

GLOBAL EYE NEWS

A fresh look at the world

WHAT ON EARTH IS IT?

Every month we post weird and wonderful images on the **How It Works** website for you to identify. We then print the best suggestions and tell you what they really are right here

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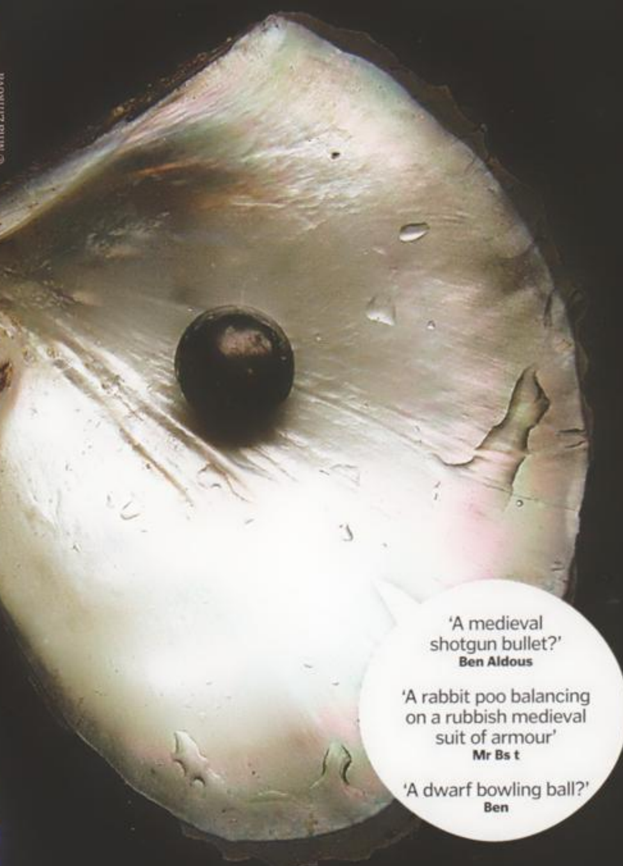
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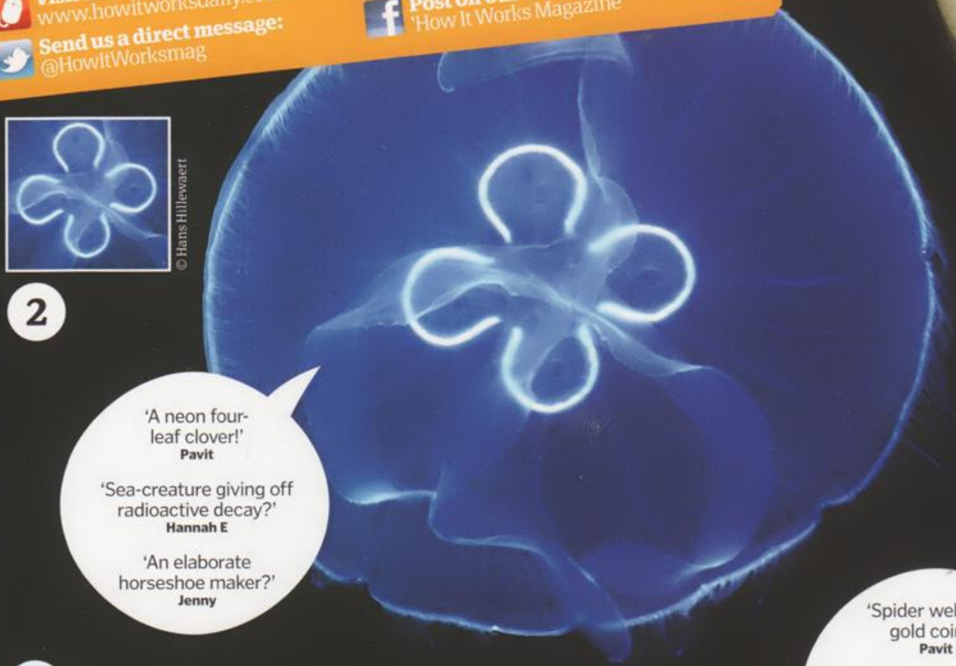
'A medieval shotgun bullet?' Ben Aldous
'A rabbit poo balancing on a rubbish medieval suit of armour' Mr Bs t
'A dwarf bowling ball?' Ben


2
'A neon four-leaf clover!' Pavit
'Sea-creature giving off radioactive decay?' Hannah E
'An elaborate horseshoe maker?' Jenny

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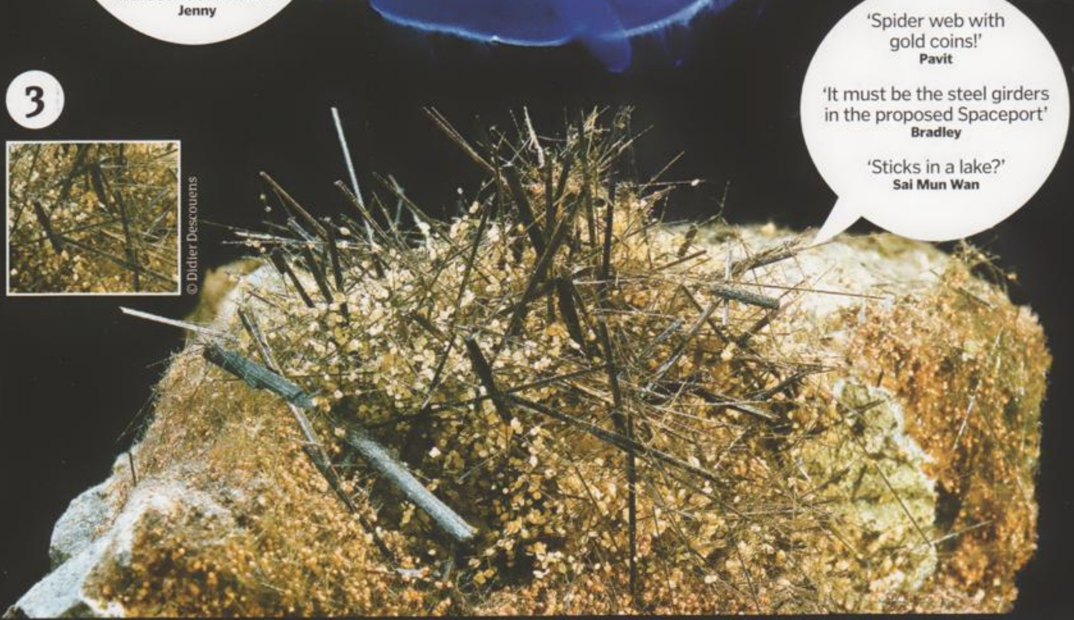
3
'Spider web with gold coins!' Pavit
'It must be the steel girders in the proposed Spaceport' Bradley
'Sticks in a lake?' Sai Mun Wan

© Didier Descouens

1. Pearl

This is a pearl produced by the black-lipped pearl oyster. Pearls are created as a side-effect of the host mollusc encasing an irritant (eg a molecule of food) inside its mantle in aragonite and conchiolin. This combination of substances produces nacre, a very resilient and iridescent material which encases the irritant and hardens into a roughly spherical prison (the pearl). The colour of a pearl depends on its host.

2. Moon

This neon marine creature is a fine specimen of aurelia aurita, which is commonly referred to as the moon jellyfish. The genus of aurelia contains more than ten morphologically near-identical species of which aurita is but one. The genus as a whole, however, can be easily identified by its characteristic horseshoe-shaped gonads as shown in the image, which are clearly recognisable through the translucent medusa.

3. Aktis

This image depicts numerous interlacing shafts of actinolite among moss. Actinolite is an amphibole silicate mineral that is commonly found in metamorphic rocks. Its name stems from the Greek word *aktis*, which translates as 'beam' or 'ray' – something that characterises the mineral's fibrous nature. Interestingly, transparent actinolite is considered extremely rare and so is prized by gem collectors.

THIS DAY IN HISTORY

26 JANUARY: How It Works issue 30 goes on sale, but what

1500 Vicente Yáñez Pinzón, a compatriot of Christopher Columbus, becomes the first European to set foot on Brazil.

1564 The Council of Trent issues its conclusions in the Tridentinum, establishing a separation between Roman Catholicism and Protestantism.

1736 King Stanislaus I of Poland abdicates his throne, receiving the Duchy of Lorraine and Bar in NE France as compensation.

1808 The Rum Rebellion takes place in Australia, the only successful armed takeover of government in the nation's history.

1838 Tennessee enacts the first prohibition law in the United States of America.

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else happened on this day in history?

1841 The United Kingdom formally occupies Hong Kong, which China later officially cedes control of.

1905 The world's largest rough gem-quality diamond ever, the Cullinan, is found at the Premier Mine in South Africa.

1965 Hindi becomes the official language of India.

2004 President Hamid Karzai signs the new constitution of Afghanistan.

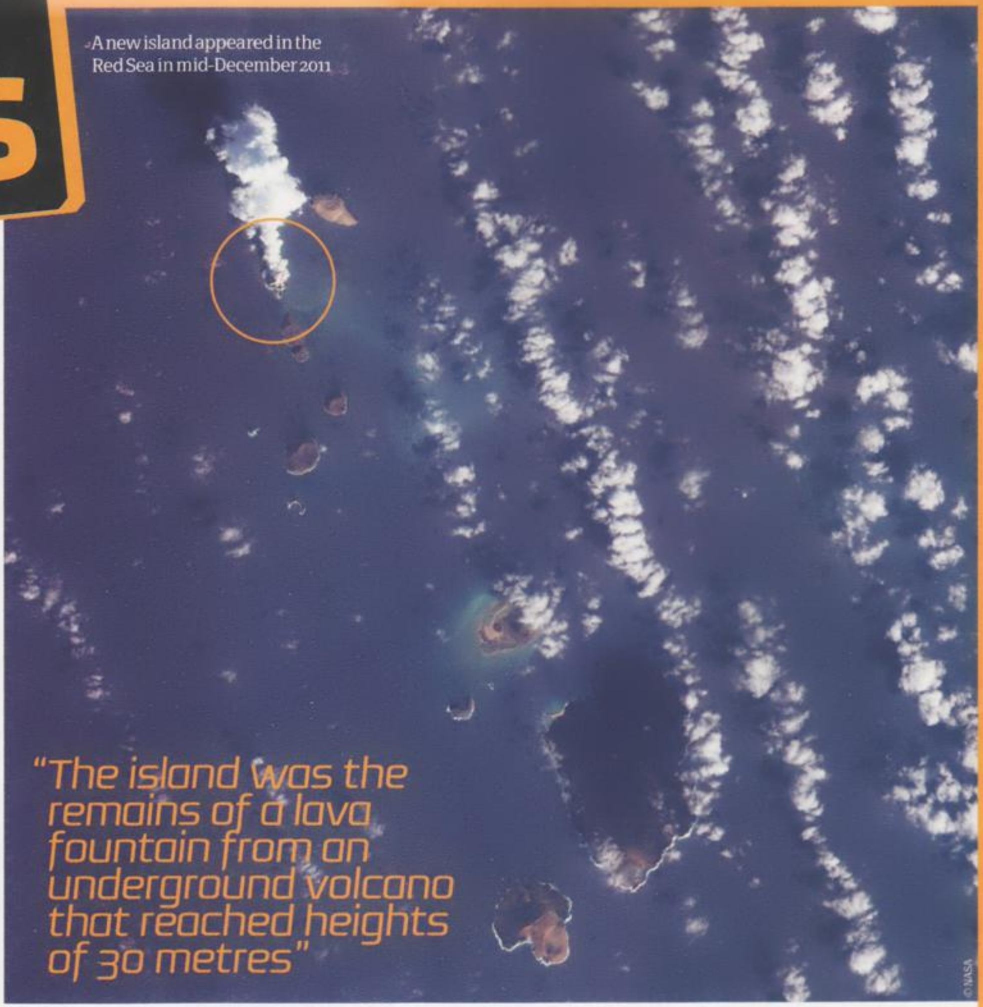
2009 Rioting breaks out in Antananarivo, Madagascar, initiating a political crisis and leading to the removal of President Marc Ravalomanana.

© Bernard Gagnon

GLOBAL EYENEWS

A fresh look at the world

10 THINGS WE'VE LEARNED THIS MONTH



A new island appeared in the Red Sea in mid-December 2011

"The island was the remains of a lava fountain from an underground volcano that reached heights of 30 metres"

© NASA

1 The 1 billion app record is broken

For the first time, the 1 billion mark has been reached in app downloads in a week. The landmark was achieved in December 2011, with new gadget owners flocking to online app stores to beef up their latest devices. In total 1.2 billion apps were downloaded in the final week of December around the world, according to analytics firm Flurry. The US was responsible for nearly half with 509 million downloads, followed by China with 99 million and the UK with 89 million.

2 Apes are gamblers just like us

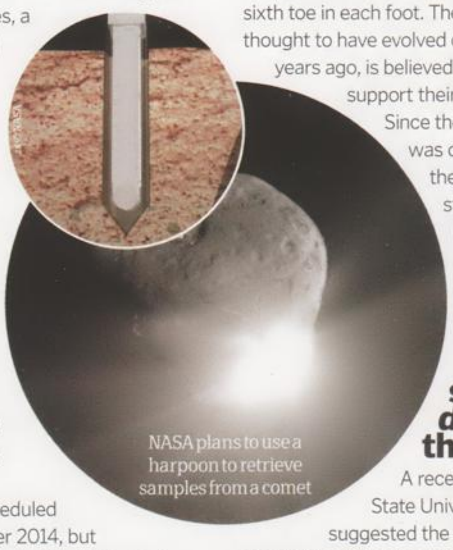
Proving humans aren't the only animals willing to take a risk, researchers at the Max Planck Institute for Psycholinguistics in the Netherlands found that apes gamble in a similar way to humans. When given a choice between a safe bet of a small piece of banana or a larger piece hidden beneath one of a number of cups, the apes chose the riskier option the majority of the time in the hope of winning the greater reward. An increase in cups also made the apes more cautious as they realised their odds of success were diminished.

3 The LHC has found a new particle

Amid the furore that was caused by a possible sighting of the Higgs boson it went largely unnoticed that elsewhere at the Large Hadron Collider – where many different experiments are carried out – an entirely new particle was discovered. Dubbed Chi_b (3P), the particle is composed of a quark and anti-quark and should help scientists understand the force that holds these two sub-atomic particles together, known as the strong nuclear force. This force also holds together protons and neutrons in atoms but, until now, it has proven hard to determine its exact nature.

4 NASA will harpoon comets

Retrieving samples from a comet is a tricky business, but NASA hopes to bring the first material from a comet's surface back to Earth by using a revolutionary new harpoon method. Instead of landing on the celestial bodies, a spacecraft would fire a harpoon that could penetrate the surface and collect samples, before being winched back to the spacecraft in orbit above the comet. The revolutionary technology is being used on the ESA's Rosetta mission to comet Churyumov-Gerasimenko, scheduled to arrive in October 2014, but unlike NASA's proposal the ESA mission will not be able to bring back samples.



NASA plans to use a harpoon to retrieve samples from a comet

5 A new island has been born

Volcanic activity in the Red Sea led to the formation of an entirely new island on 19 December 2011. Currently unnamed, the island was the remains of a lava fountain from an underground volcano that reached heights of 30 metres (90 feet). The eruption, off the west coast of Yemen, was seen by local fishermen.

6 Elephants have six toes

In a remarkable discovery that has eluded scientists for centuries, it has been revealed that elephants have a hidden sixth toe in each foot. The additional digit, thought to have evolved over 40 million years ago, is believed to help elephants support their huge weight. Since the first elephant was dissected in 1706, the additional structure was regarded as a useless piece of cartilage.

7 Slow and steady *does* win the race

A recent study at Ohio State University has suggested the increased decision-making time often seen in elderly people helps ensure accuracy over speed. While people of a younger generation tend to be quicker to jump to a conclusion, the more aged among us deliberate slightly longer to ensure the response is correct.

8 The Mars rovers are eight years old

On 3 January 2004, NASA's golf cart-sized Mars rover Spirit landed on the Red Planet before being joined, three weeks later, by its sister, Opportunity. 2012 sees the rovers enter their eighth year on Mars and, although only Opportunity is still active, the rovers have exceeded all expectations, having been originally expected to last only 90 days. Combined, they've covered a distance of 42 kilometres (26 miles).

9 Hackers plan their own internet

In an attempt to combat the controversial Stop Online Piracy Act (SOPA) currently being considered in the USA, which has been widely derided for threatening to create a censored internet akin to that in China, hackers have proposed a plan to launch space satellites into Earth orbit and run their own separate world wide web.

10 Birds can count

Researchers at the University of Otago in New Zealand have announced pigeons appear to possess the ability to count. The pigeons were trained to peck a touchscreen a certain number of times depending on how many objects appeared, with a reward for a correct response. Results showed that the birds performed the task as well as monkeys.

GLOBAL EYE
OPINION
TECHNOLOGY COLUMNIST
POLLYANNA WOODWARD

Personal flight for all

Technology devotee Pollyanna gets a taste of the superhero lifestyle on her latest gadget trip to the States

© Anna Fowler

Being a presenter on *The Gadget Show*, I've been lucky enough to experience some unbelievable things. I've travelled to breathtaking places and seen things that, as a child, I wouldn't have believed would ever become a reality, but every day my eyes are opened to this intriguing world of vision, creativity and dreams, where fiction and fantasy are rapidly becoming real and tangible.

For the 16th series of the show, I flew to America on a quest to test some of the world's latest and greatest technological creations; this is one journey that certainly didn't disappoint. I started in Chicago, flew to Texas and ended my trip in Florida's Key West, where I tested one of the most unforgettable and exciting new creations in the world of personal transport, and though I had to face my fear using this tech, it opened my eyes to how close we are to being superheroes.

Let me introduce you to the JetLev R200. This is a water-powered jet pack that enables you to levitate over water up to nine metres (30 feet), move forwards, back, left and right; it can also propel you into the water to the same depths. This is a light carbon-fibre back panel seat that has what is essentially two hoses strapped to it either side. There's also a hose that attaches to a self-contained pod, which sits on the water's surface and forces the water up to the jet hoses. This pod allows you to be completely independent on the water so you can freely navigate wherever you want. The pod attached to the pack also carries the fuel for the system and, on one full tank, you'd have enough juice to get you across the English Channel and back again.

Now, I am pretty fearless. To an extent I would even class myself as an 'adrenaline seeker', but one thing I've never been fond of is open water, so getting to grips with the JetLev wasn't the smoothest lesson, and to initially get it out of the water proved tricky. One incorrect movement of your arms and it will propel you underwater and even though there was a safety pull it was still quite a daunting prospect for me.

I had my first test flight and it was crazy. It is one of the hardest sensations to try and describe – there were so many emotions happening at the same time: anticipation, excitement, fear, exhilaration, plus having to concentrate so hard. It was very tense, but I surprised myself with how quickly I got to grips and became quite at ease with it. I'm sure we've all watched movies like *Iron Man* and wondered what that kind of personal flight must feel like... and there I was experiencing it. While this is a very new piece of technology, I'm not the only one who can try it out; if you are visiting Key West the JetLev is available for hire, so you too can pretend to be Iron Man, even if it is only for 20 minutes... Believe me, that's plenty of time to get your superhero fix.

"On one full tank, you'd have enough juice to get you across the English Channel and back again"

The jets propel you up to 9m (30ft) off the water's surface

The JetLev is available for public hire in Key West, FL – makes a change from SeaWorld!

3x © JetLev

Black holes go large

This month in **Space**

Be prepared to get sucked in to our lead feature in Space, as we explore the ins and outs of not just regular black holes, but supermassive ones too. Incredibly there's one located at the heart of our very own Milky Way, but how did it get there? Next, **How It Works** picks ten of the top space missions of all time, revealing how each of them has advanced our knowledge of the cosmos. Also covered are the GRAIL probes studying our moon in depth, the science behind spectrography and what makes a dwarf planet.

16 Evolution of spacecraft

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20 Dwarf planets

SPACE

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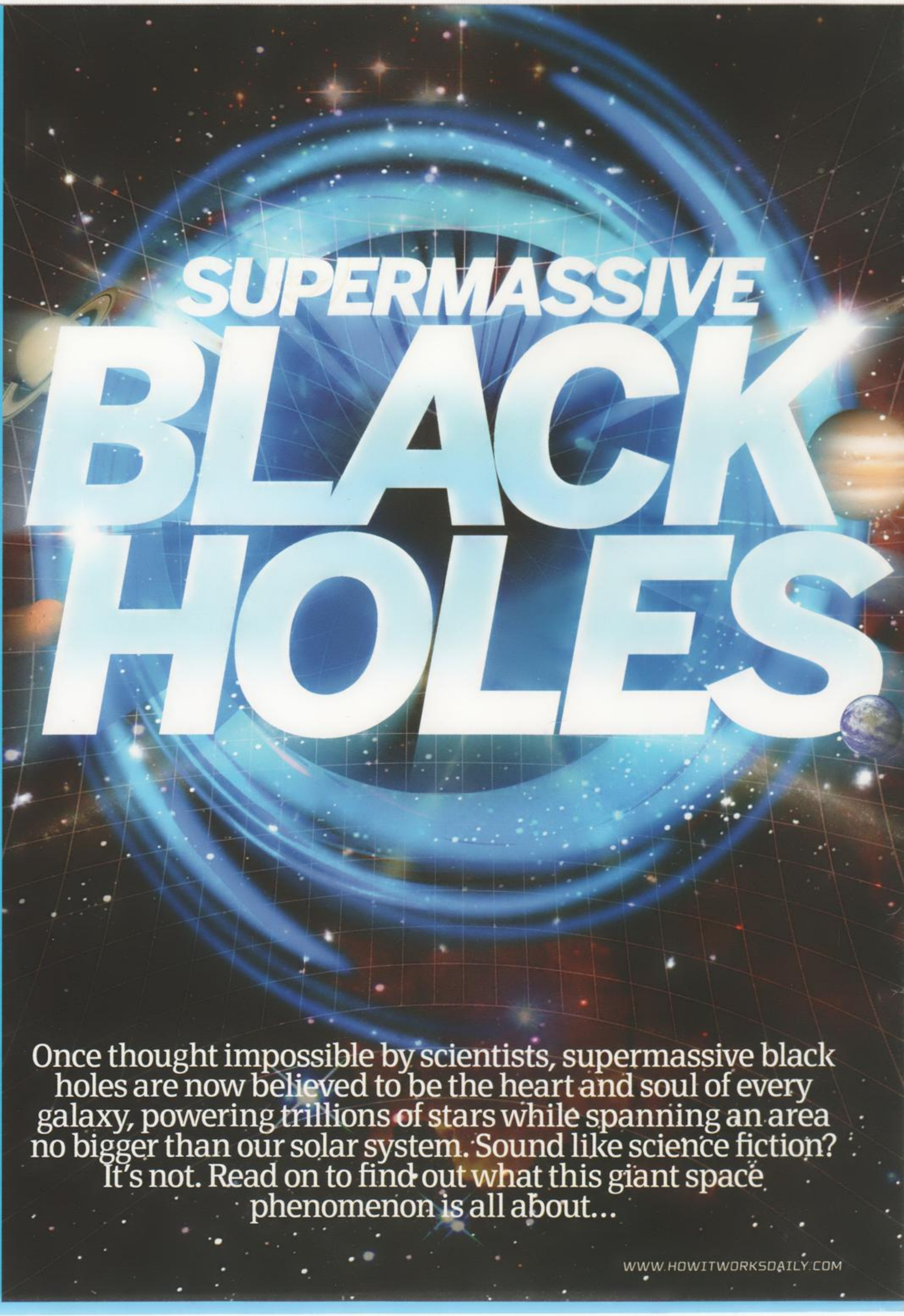


SUPERMASSIVE BLACK HOLES

Once thought impossible by scientists, supermassive black holes are now believed to be the heart and soul of every galaxy, powering trillions of stars while spanning an area no bigger than our solar system. Sound like science fiction? It's not. Read on to find out what this giant space phenomenon is all about…

Head to Head NEAREST BLACK HOLES

MINI

© NASA

1. Earth's atmosphere

Collisions between cosmic rays and particles in our very own atmosphere could be making thousands of miniature black holes.

MASSIVE

© ESO

2. V4641 Sagittarii

This black hole can be found just over 20,000 light years away in the Sagittarius constellation in a binary star system.

SUPERMASSIVE

© NASA

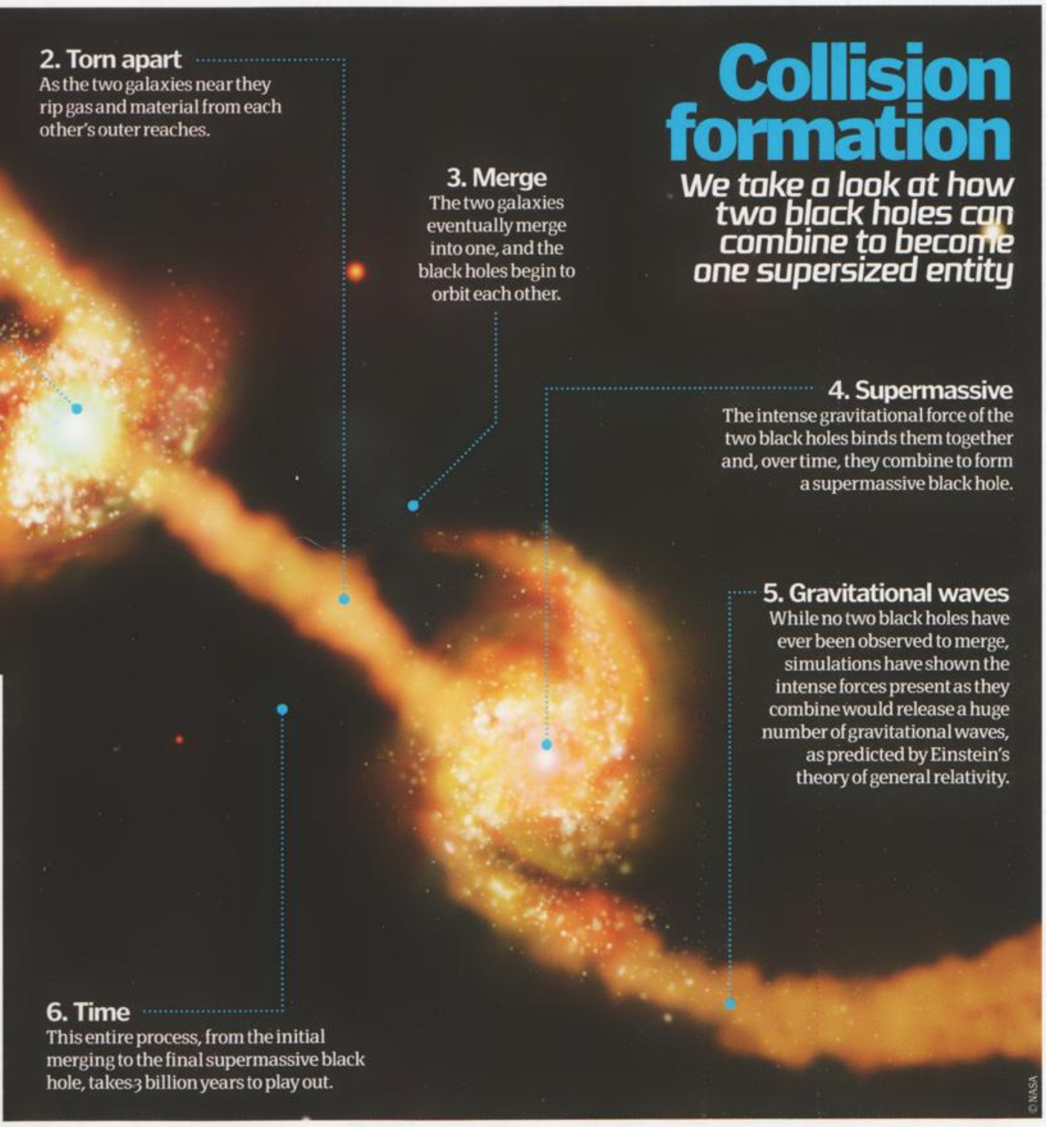
3. Sagittarius A*

This supermassive black hole is located at the centre of the Milky Way galaxy. It too is in the Sagittarius constellation and is approximately 26,000 light years from Earth.

DID YOU KNOW? About 15 per cent of the mass of a galaxy's central bulge is located within a black hole

Collision formation

We take a look at how two black holes can combine to become one supersized entity



1. Galaxy collision
Supermassive black holes can form when two galaxies in the same region of space are drawn together.

2. Torn apart
As the two galaxies near they rip gas and material from each other's outer reaches.

3. Merge
The two galaxies eventually merge into one, and the black holes begin to orbit each other.

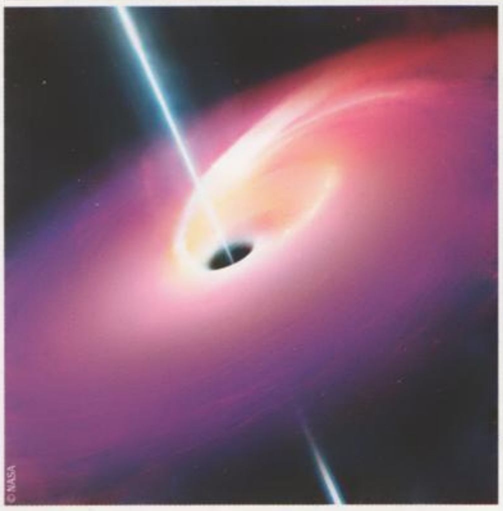
4. Supermassive
The intense gravitational force of the two black holes binds them together and, over time, they combine to form a supermassive black hole.

5. Gravitational waves
While no two black holes have ever been observed to merge, simulations have shown the intense forces present as they combine would release a huge number of gravitational waves, as predicted by Einstein's theory of general relativity.

6. Time
This entire process, from the initial merging to the final supermassive black hole, takes 3 billion years to play out.

© NASA

A supermassive black hole has the mass of at least a million suns


© NASA

When black holes were first theorised, many scientists thought their existence was a physical impossibility.

How could an object exist from which nothing, not even light, could escape? And how could this phenomenon be large enough to power a galaxy? To this day many questions remain unanswered about these statistical nightmares, but there's little doubt now that they're real. But just how extraordinary are they?

As you might have guessed, a supermassive black hole (SMBH) contains a lot of mass, roughly equivalent to between a million or several billion suns. While regular black holes can be found propagating the universe as a whole, often left as remnants of a star going supernova, SMBHs are much less common but exceedingly more powerful. To date, every SMBH that has been discovered is located at the centre of a galaxy, indicating that this fascinating phenomenon is not only responsible for giving birth to and maintaining galaxies, but also destroying them. It is strongly believed that an SMBH lurks at the heart of nearly every galaxy, heating the stars and material in its vicinity in addition to recycling matter for the formation of new planets, stars and, in extreme cases, entirely new galaxies. Indeed, at the centre of our own Milky Way, 26,000 light years from Earth, resides the SMBH known as Sagittarius A*.

The realisation that supermassive black holes could be the power sources for galaxies got scientists wondering just how large these things could really become. In early December 2011 astronomers announced they had discovered the largest SMBH in the known universe. Located in the NGC 4889, or Caldwell 35, galaxy around 336 million light years from Earth, this SMBH contains the mass of 21 billion suns. Scientists analysed data from the Hubble Space Telescope, in addition to the ground-based telescopes Gemini North and Keck II in Hawaii, to find this behemoth. It eclipses the previous largest known SMBH by more than three times.

The reason these black holes can grow quite so big is due to the extreme conditions in which they are formed, with two primary methods currently favoured. The collision theory states that two or more colliding black holes can become gravitationally bound to create an SMBH, while quasar theory suggests newly forming galaxies will eventually pump so much matter into a regularly sized black hole that it will expand to a humongous size over a long enough period. Quasars are the expanses of matter surrounding a black hole and are regarded as the brightest objects in the universe. As a black hole pulls matter in, it swirls around it in a quasar stretching thousands of light years across.

At the very centre of a supermassive black hole is a phenomenon known as a singularity. This might be impossible to believe, but a singularity is no bigger than the full stop at the end of this sentence, but contains more mass than a billion suns. In fact, the exact physics of a singularity are nigh-on impossible to comprehend, and scientists continue to be baffled by these statistically impossible condensations of matter. Theoretically they contain the majority of the black hole's mass and thus are infinitely dense, but their existence is difficult to prove and so they remain highly controversial.

The gravitational pull this singularity – and ultimately the entire black hole – exerts is huge, to say the least. As mentioned previously, nothing can escape from a black hole, not even light itself. However, all hope is not lost if you stray too close. ▶

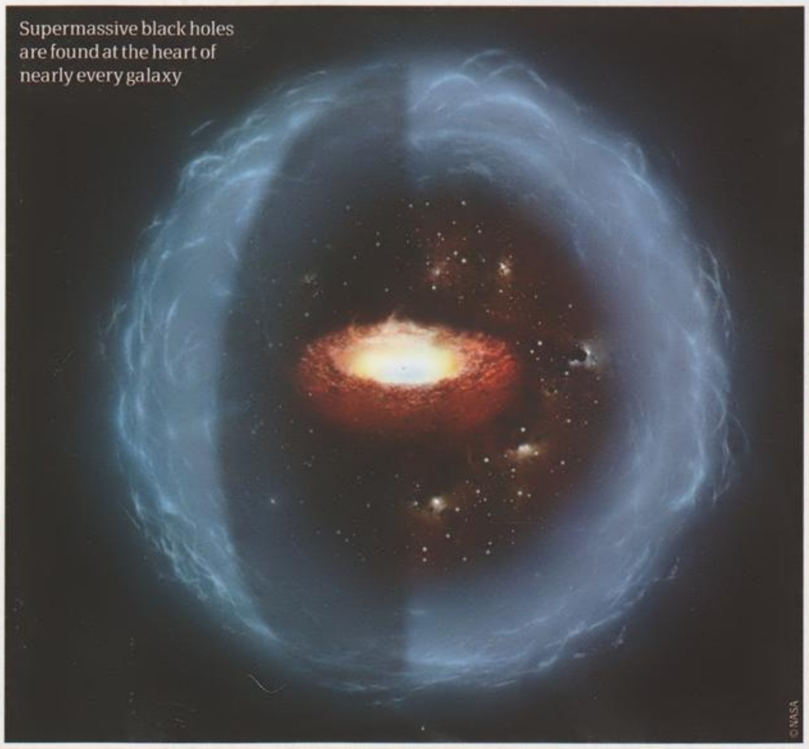
> "SMBHs might be terrifying to imagine, but they're integral to both the formation and upkeep of galaxies"

The extent to which a supermassive black hole's gravity is inescapable extends outwards several million miles to an area known as the event horizon. This is the point of no return, where once matter (and light) passes, it will no longer be able to get away. Surrounding the event horizon is the quasar. Depending on its age, however, something rather odd happens inside the event horizon of a supermassive black hole.

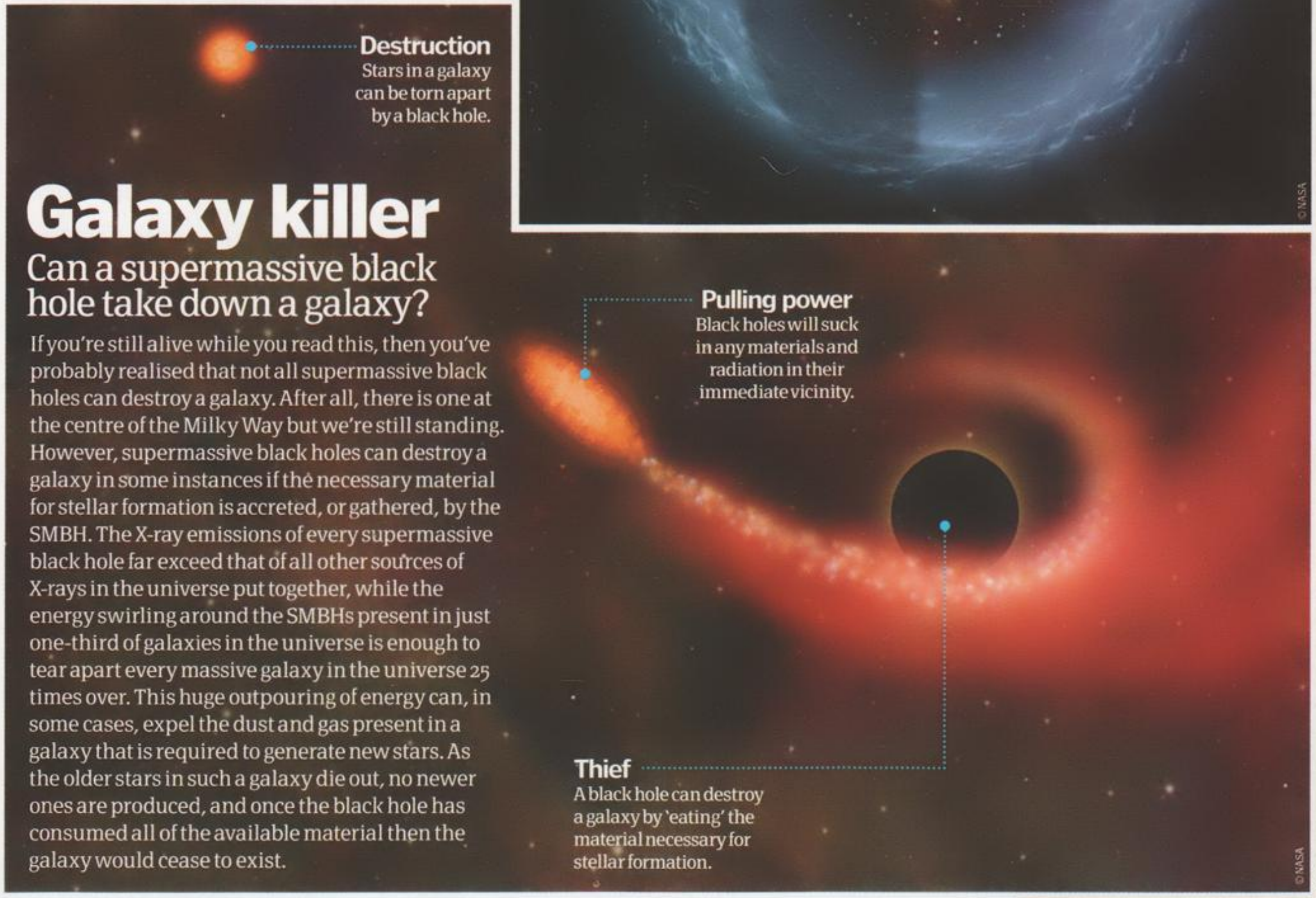
While black holes can consume a huge amount of energy and material, they cannot eat an infinite amount. Once it has reached its limit, it can no longer store matter, and instead fires material out vertically, in both directions, as giant jets of energy. These jets can be 20,000 light years across, sending huge amounts of energy (mostly X-rays) into the universe. It is via these jets that the majority of supermassive black holes have been found, as most galaxies can be observed to fire out these blasts of energy. However, as a galaxy ages, the SMBH will accrete less and less matter, eventually becoming almost stable as the remaining nearby material orbits the event horizon inside the quasar. At this point the jets will cease firing.

SMBHs have been around since the start of the universe, forming not only through the two methods we look at here but also through the combination of smaller and smaller black holes. At the dawn of the universe, roughly 14 billion years ago, large clouds of dust and gas drifted free. However, as proven by experiments at giant particle accelerators, such as the Hadron at CERN, the collisions between atoms produced mini black holes. Over time these would be pulled together by gravity into larger regular-sized black holes until, after hundreds of millions of years, supermassive black holes were created at the centre of these dust and gas clouds, in turn spurring the creation of new stars and subsequently entire galaxies.

These ancient but almost everlasting power generators might be terrifying to imagine, but there's little doubt that they're integral to both the formation and general upkeep of galaxies. It's unlikely we'll ever visit one ourselves, but from afar we can observe these cosmological wonders in the detail necessary to appreciate the job they do to keep the universe ticking over.


Supermassive black holes are found at the heart of nearly every galaxy

© NASA


Destruction Stars in a galaxy can be torn apart by a black hole.

Pulling power Black holes will suck in any materials and radiation in their immediate vicinity.

Thief A black hole can destroy a galaxy by 'eating' the material necessary for stellar formation.

© NASA

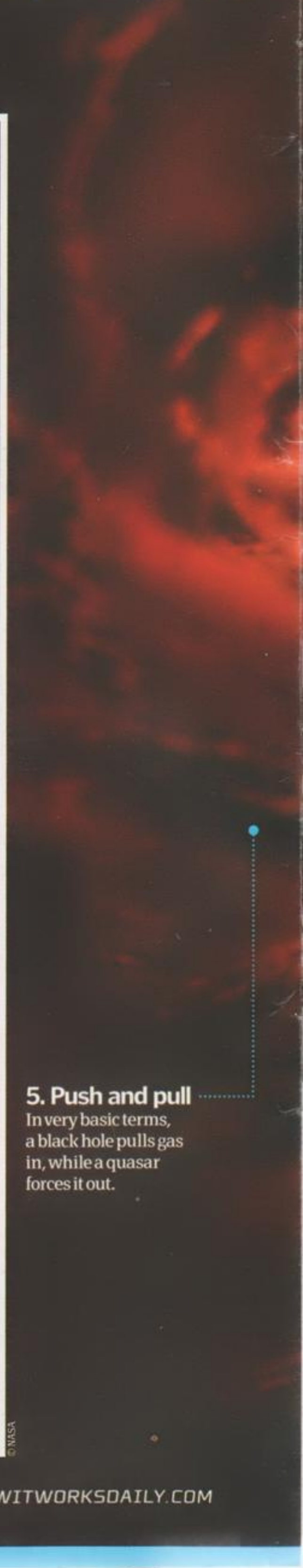
Galaxy killer

Can a supermassive black hole take down a galaxy?

If you're still alive while you read this, then you've probably realised that not all supermassive black holes can destroy a galaxy. After all, there is one at the centre of the Milky Way but we're still standing. However, supermassive black holes can destroy a galaxy in some instances if the necessary material for stellar formation is accreted, or gathered, by the SMBH. The X-ray emissions of every supermassive black hole far exceed that of all other sources of X-rays in the universe put together, while the energy swirling around the SMBHs present in just one-third of galaxies in the universe is enough to tear apart every massive galaxy in the universe 25 times over. This huge outpouring of energy can, in some cases, expel the dust and gas present in a galaxy that is required to generate new stars. As the older stars in such a galaxy die out, no newer ones are produced, and once the black hole has consumed all of the available material then the galaxy would cease to exist.

Quasar formation

Another theory of how supermassive black holes are formed is when a young galaxy reaches maturity. But how does this work in practice?


5. Push and pull In very basic terms, a black hole pulls gas in, while a quasar forces it out.

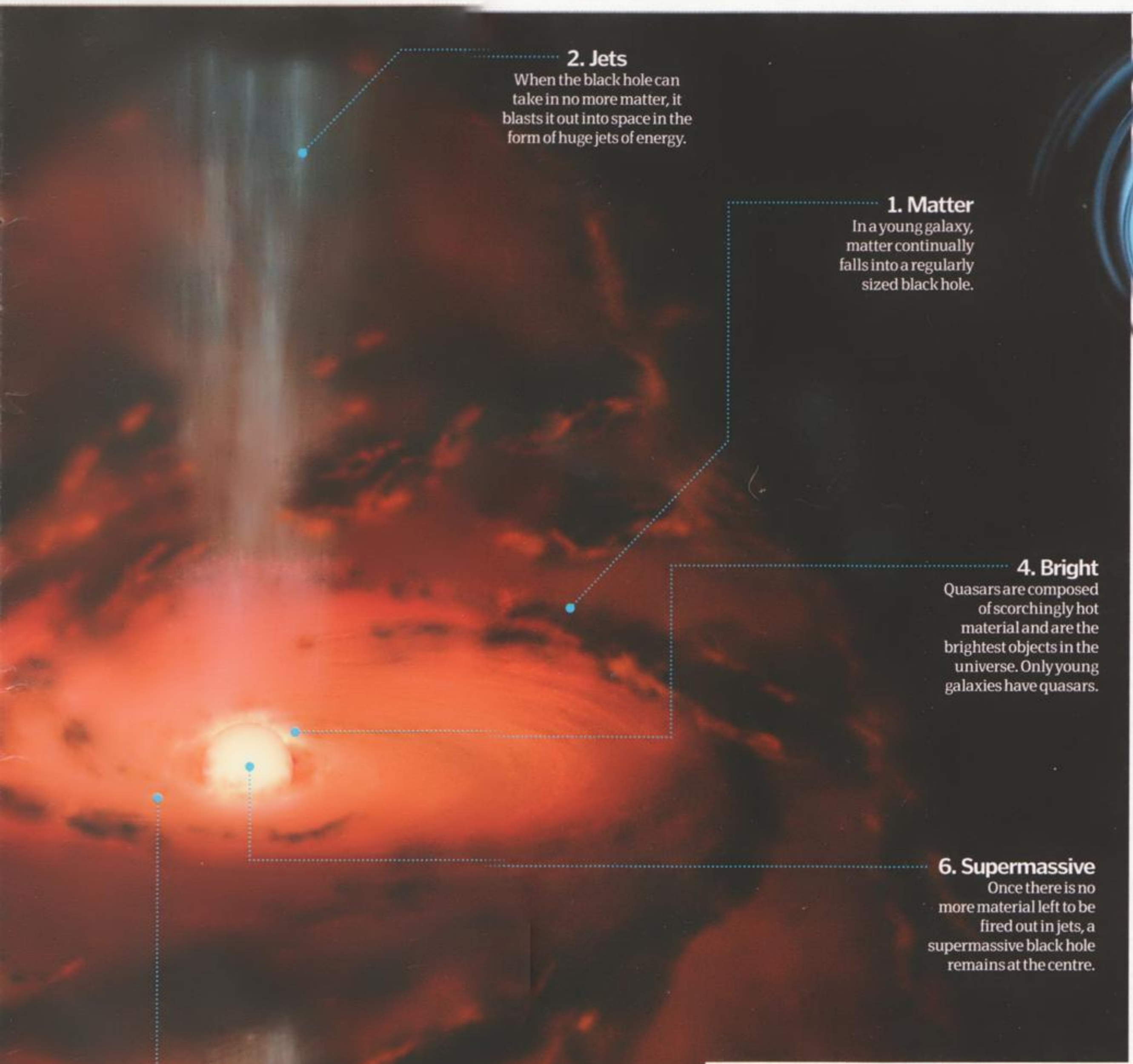
© NASA

DID YOU KNOW?

Could a black hole destroy Earth?

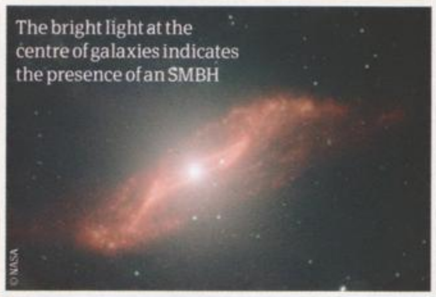
The estimated odds of the Earth being destroyed by a black hole are approximately one in a trillion. There is simply no black hole close enough to our solar system to swallow Earth and, even if a black hole with the same mass as the Sun took its place, Earth's orbit would not change.

DID YOU KNOW? If a star 1 million times the mass of the Sun collapses, it will form a supermassive black hole

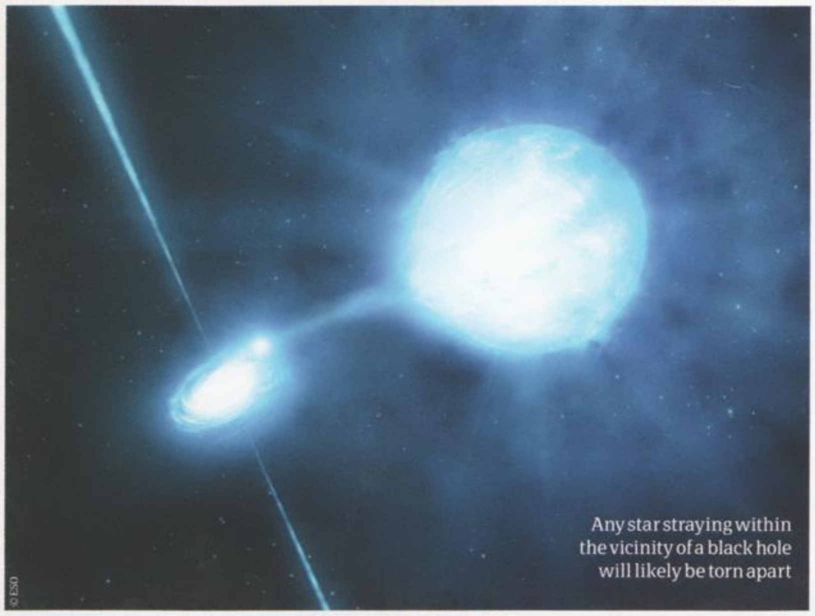

2. Jets
When the black hole can take in no more matter, it blasts it out into space in the form of huge jets of energy.
1. Matter
In a young galaxy, matter continually falls into a regularly sized black hole.
4. Bright
Quasars are composed of scorchingly hot material and are the brightest objects in the universe. Only young galaxies have quasars.
6. Supermassive
Once there is no more material left to be fired out in jets, a supermassive black hole remains at the centre.
3. Quasar
Eventually the material heats up and no more can be taken in, forming a super-hot quasar around the black hole.

BLACK HOLE TIME TRAVEL

Could a supermassive black hole be used to travel forward in time? Stephen Hawking certainly thinks so. He suggests – theoretically – if a spaceship orbited a black hole 24 million kilometres (15 million miles) in diameter beyond the distance at which it would be pulled in (approximately a further 15 million miles), time would slow down for the crew on board. One full orbit would take the spaceship 16 minutes, according to observers watching from Earth, but for the crew each orbit would only take eight minutes. If they did this for ten Earth years, when they returned home 20 years would have passed. Hawking puts this down to the interaction with space and time, as the gravitational pull of an SMBH affects space-time and alters conditions for those in its vicinity.


The bright light at the centre of galaxies indicates the presence of an SMBH

© NASA


Any star straying within the vicinity of a black hole will likely be torn apart

© ESO

SPACE TRAVEL

We take a look at the ten most important space missions of all time

Since Russia's Sputnik 1 satellite entered space on 4 October 1957, thousands of spacecraft, including Earth satellites and deep-space probes, have launched into the cosmos.

In those five decades space travel has truly come on leaps and bounds, with the development of liquid and solid fuels, and the use of solar panels and radioactive power sources among many of the impressive innovations, allowing space agencies across the planet to undertake evermore ambitious missions that would once have never been thought possible. Here, **How It Works** has compiled ten of the most successful missions that have advanced the field of space travel to a whole new level. ✱

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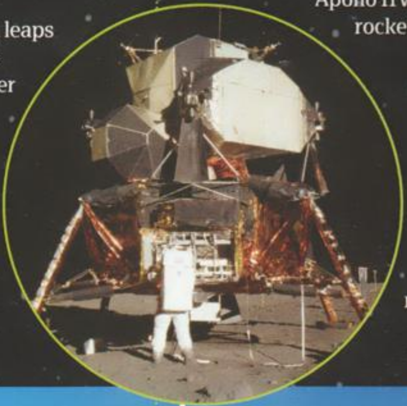


1969

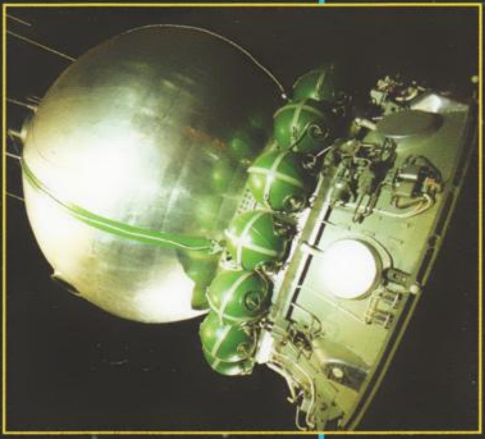
Apollo 11

Probably the most well-known space mission of all time, Apollo 11 was launched atop the most powerful rocket to date, the Saturn V. The spacecraft was composed of two sections – the Lunar Module and the Command Module – the latter of which remained in orbit around the moon with Michael Collins on board while the former took astronauts Neil Armstrong and Buzz Aldrin to the surface. Apollo 11 paved the way for a further five successful missions to the moon, each spending several days on the lunar surface.

1960s

1970s

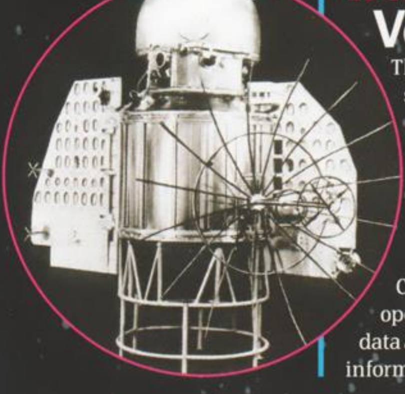
1980s



1961

Vostok 1

In 1961 Yuri Gagarin became the first man to travel to space, and the spacecraft that took him there for 68 minutes, was a fairly rudimentary sphere known as Vostok 1. As this was the first manned craft to leave Earth orbit, lots of extra precautions were taken, eg Gagarin was not able to freely move around the cabin, nor was he able to manually control the spacecraft. Nonetheless, in the timeline of space exploration, Vostok 1 is without a doubt one of the most important spacecraft of all time.



1961-1984

Venera probes

The Venera missions have been Russia's most successful space exploration missions to date. In total, 23 separate probes were launched to the hottest planet in our solar system, Venus, between 1961 and 1984, with ten of these landing on the surface. Each Venera lander was a technical marvel, withstanding incredible temperatures of up to 462 degrees Celsius (864 degrees Fahrenheit) to remain operational for up to two hours. They returned key data about the surface of Venus, including detailed information on the planet's atmospheric structure.

1977-present

Voyager 1 and 2

The Voyager programme was originally designed to explore Jupiter, Saturn, Uranus and Neptune, but the mission was extended to include the boundary into interstellar space, which they are currently entering. The Voyager probes both receive power from three radioisotope thermoelectric generators, fed by plutonium-238. On board each probe is a variety of sounds and images known as the Golden Record, which also contains instructions on how to find Earth for any passing aliens.

1972-2003

Pioneer 10 and 11

The purpose of the Pioneer missions was to learn about the outer reaches of the solar system. These two spacecraft were, at the time of their launch, the most advanced vehicles to venture into space. They contained a number of technical tools never used before, including a charged particle instrument to measure the extent of the Sun's influence. While comms were lost in 1995 (Pioneer 11) and 2003 (Pioneer 10), the probes continue to make their way out of the solar system, with each possessing an on-board plaque detailing their origins.

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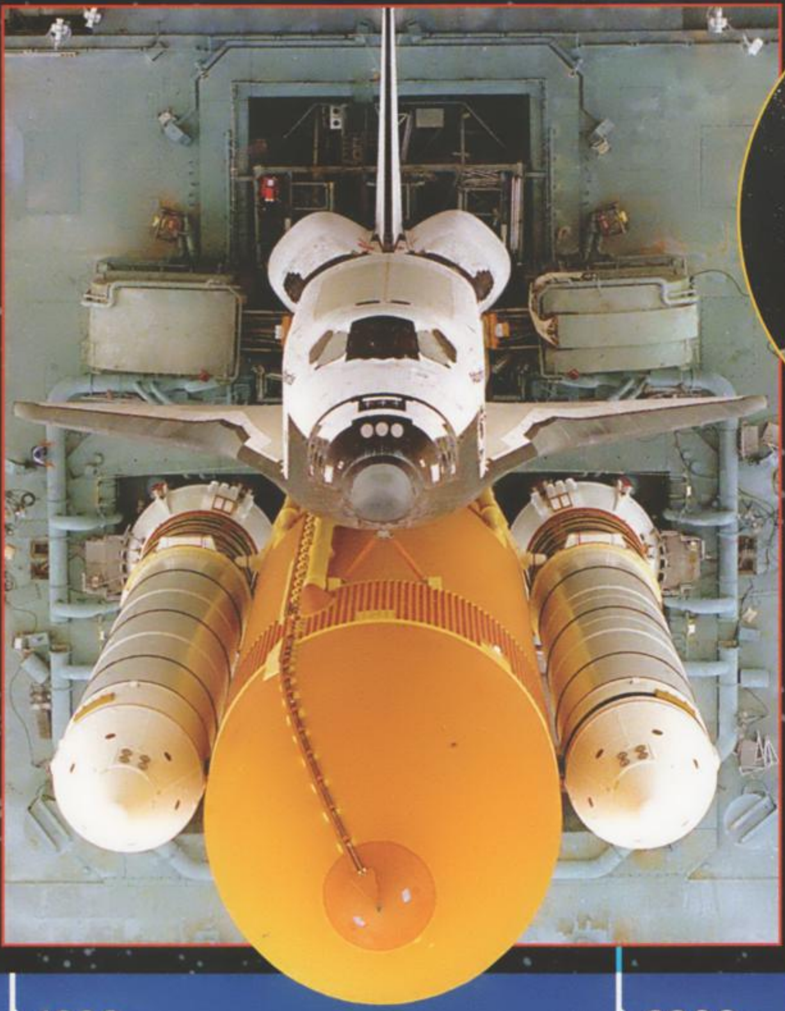
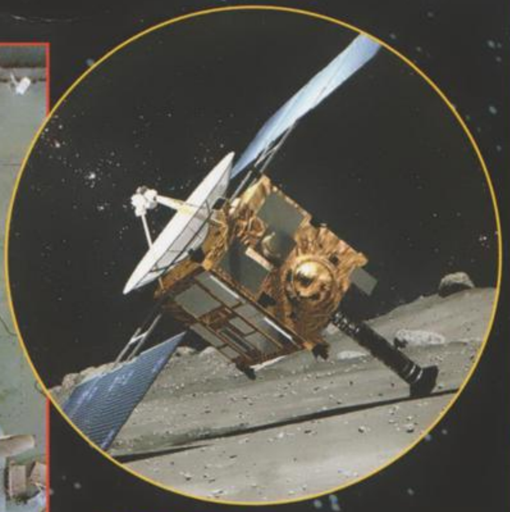


1981-2011

Space Shuttles

NASA's five cosmos-faring Space Shuttles were the largest spacecraft of all time, and each completed numerous missions that defined them as some of the most important vehicles to enter Earth orbit. Their many accolades include taking the Hubble Space Telescope into orbit (and later repairing it) and launching more than 80 per cent of the modules for the ISS. There were 135 missions in total, but two of these ended in tragedy. The Challenger spacecraft exploded 73 seconds after launch in 1986, while in 2003 the Columbia spacecraft was torn apart on re-entry. While the Shuttles are remembered largely as a success, these two disasters serve as a reminder of just how dangerous space travel is.



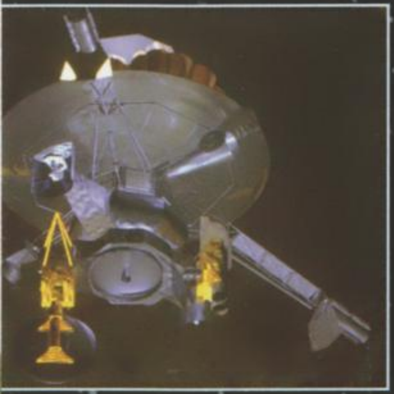
2003-2010

Hayabusa

Japan's Hayabusa probe was the first spacecraft to return a sample from an asteroid, but it wasn't without its problems. A fuel leak rendered its chemical engines unusable and, coupled with a variety of mechanical failures, the probe was forced to limp home on its weaker ion engines. It eventually arrived three years behind schedule in 2010, but the mission was still a success. Ion engines on spacecraft have become more and more popular due to their longevity, rather than relying on an initial big 'push'.

1990s

2000s



1989-2003

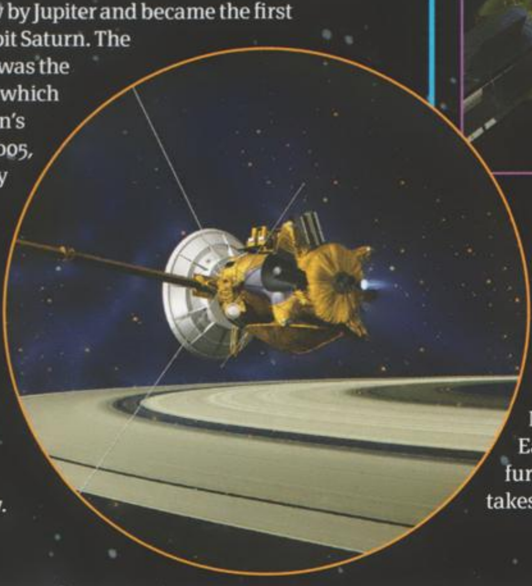
Galileo probe/ spacecraft

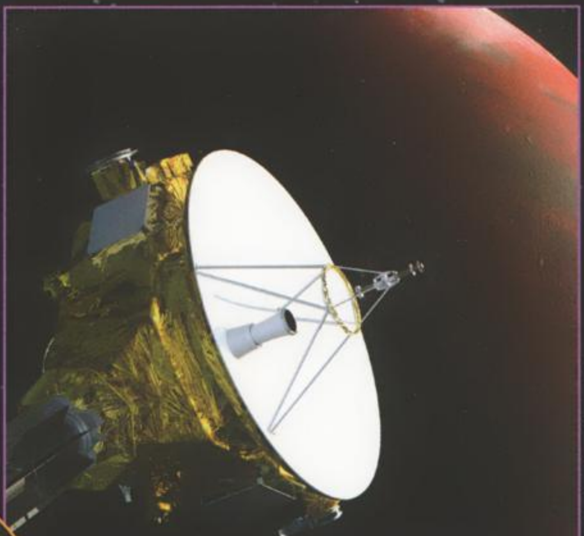
NASA's Galileo spacecraft was taken into space in 1989 and went on to study Jupiter after flybys of Venus and Earth. It was the first spacecraft to orbit Jupiter, in addition to performing the first flyby of an asteroid. It also carried the Galileo Space Probe, which it released into Jupiter's atmosphere in 1995, providing unprecedented data about the gas giant. In 2003 the orbiting spacecraft was sent crashing into our solar system's biggest planet to prevent it colliding with a nearby moon and causing contamination.

1997-present

Cassini-Huygens

The Cassini-Huygens probe was a joint mission between NASA, the ESA and ASI (Italian Space Agency) and is often regarded as the most successful deep-space probe of all time. The orbiting component of the probe flew by Jupiter and became the first spacecraft to orbit Saturn. The landing vehicle was the Huygens Probe, which landed on Saturn's moon Titan in 2005, the first and only successful landing in the outer solar system. As with most probes, it is powered by plutonium-238, which has enabled its mission to be extended to 2017.





2006-present

New Horizons

NASA's New Horizons spacecraft will become the first probe to fly by Pluto in 2015. While its primary mission is to study the (now) dwarf planet, it has also studied Jupiter and its moons. New Horizons is the fastest probe to have left Earth's orbit. It is currently more than 21 times further from the Sun than Earth; at that distance it takes almost three hours to send or receive a signal.

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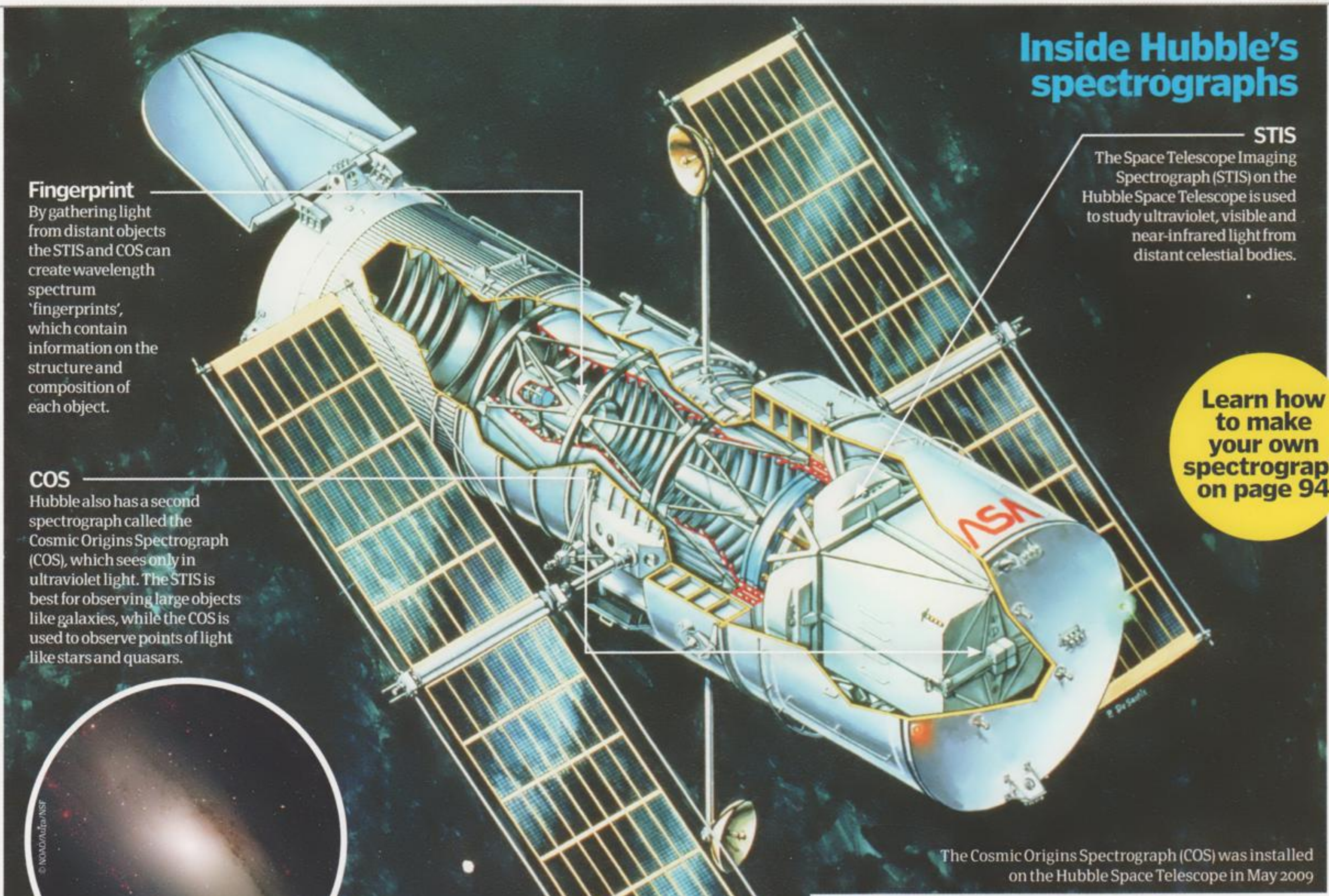
> "A spectrometer is an instrument that is used to analyse electromagnetic spectrums"

Inside Hubble's spectrographs



STIS
The Space Telescope Imaging Spectrograph (STIS) on the Hubble Space Telescope is used to study ultraviolet, visible and near-infrared light from distant celestial bodies.

Fingerprint
By gathering light from distant objects the STIS and COS can create wavelength spectrum 'fingerprints', which contain information on the structure and composition of each object.

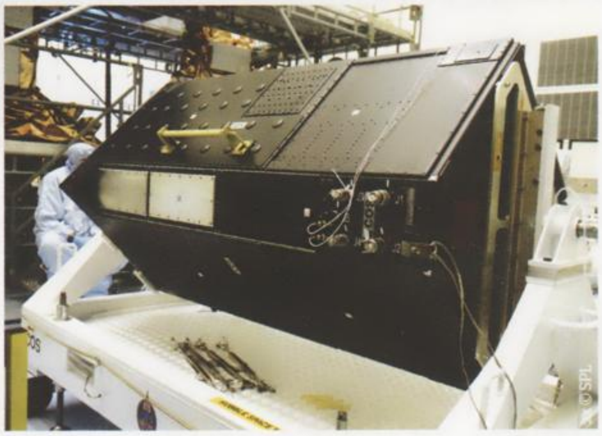
COS
Hubble also has a second spectrograph called the Cosmic Origins Spectrograph (COS), which sees only in ultraviolet light. The STIS is best for observing large objects like galaxies, while the COS is used to observe points of light like stars and quasars.

Learn how to make your own spectrograph on page 94

Spectrography can be used to measure the composition of distant stars and galaxies

© NOAO/AURA/NSF

The Cosmic Origins Spectrograph (COS) was installed on the Hubble Space Telescope in May 2009



© SPL

Spectrography

How can we determine the composition of a distant star?

Spectrography, or spectroscopy, is the study of light from distant objects (such as a black hole or galaxy) to analyse their composition, movements and structure.

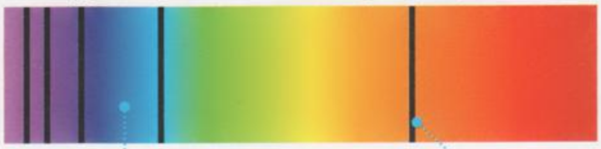
It works by measuring the intensity of light present across a range of energies on the electromagnetic spectrum. Every element in the universe has a particular pattern of black lines, known as emission lines, unique to that element on the spectrum. By matching the known emission lines of an element to those observed on a spectrum from an object, the composition can be determined.

A spectrometer is an instrument that is used to analyse these electromagnetic spectrums. In practice, it does this by observing the light (be it visible, infrared or otherwise) emitted from a source, and deducing the various energies associated with that light. Depending on the elements that are present in a celestial body, the spectrum it produces will be different to that from any other body.

Spectrometers are used on a variety of space telescopes, including the Hubble Space Telescope (see the above diagram), but they can also be used here on Earth to study not only distant space phenomena but objects on our planet too, like plants and minerals. Spectrography is very useful in astronomy, providing us with the answers to how stars form, what they are made of and more.

Hydrogen spectrograph

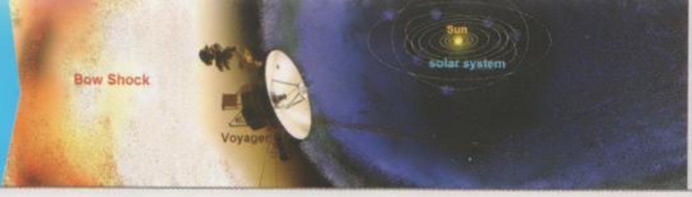
Discover how the emission of hydrogen from a star appears on the electromagnetic spectrum



Photons
Energy is released by elements as photons, which produce the observable lines on a spectrum.

Pattern
By matching the pattern of lines with existing spectrographs, scientists can establish what they are looking at.

DID YOU KNOW?



Voyager shock

NASA's Voyager probes are currently at the edge of the solar system. Here, they have observed a significant decrease in the solar wind, suggesting that they have found the Sun's bow shock at the boundary of interstellar space. It is roughly 230 times further from the Sun than Earth.

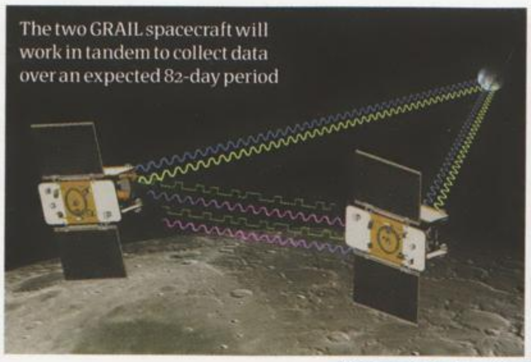
DID YOU KNOW? *At the end of their mission the GRAIL probes will be crashed into the surface of the moon*

GRAIL probes

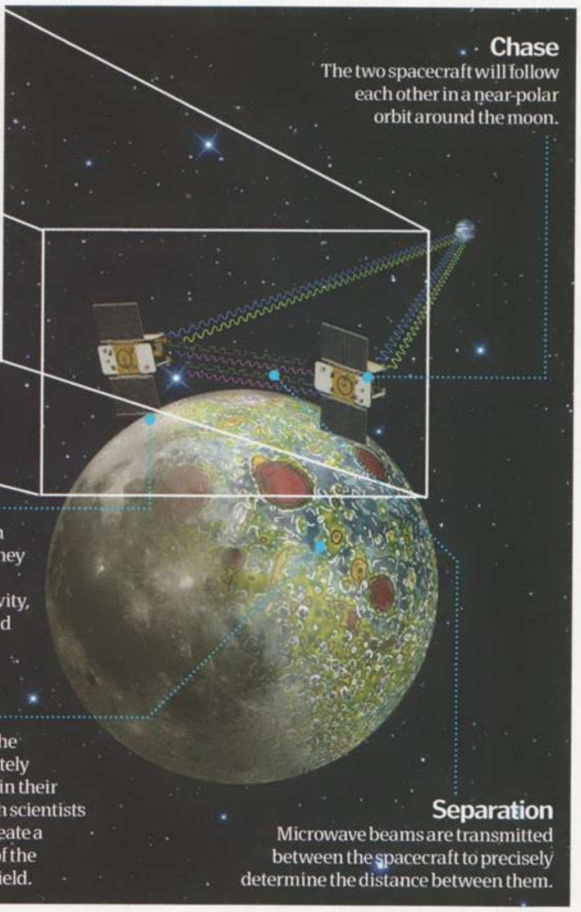
The spacecraft that will study the moon in prodigious detail

NASA's Gravity Recovery and Interior Laboratory (GRAIL) mission is studying the moon's gravity in unprecedented detail, using two spacecraft 50 kilometres (30 miles) above its surface. Each spacecraft – GRAIL-A and GRAIL-B – weighs 202 kilograms (445 pounds) and is the size of a washing machine. The two probes will chase each other around the lunar surface in a near-polar orbit. On board each is a lunar gravity ranging system (LGRS), which monitors the distance between the spacecraft down to a few microns (the diameter of a red blood cell), allowing the influence of the moon's gravity on the spacecraft to be accurately recorded. A similar experiment called GRACE (Gravity Recovery and Climate Experiment) has been performing a near-identical manoeuvre to map the gravity of the Earth since 2002.

After launching in September 2011 it took the GRAIL spacecraft almost four months to reach the moon. The journey normally would only take around three days, but NASA opted to use a lengthier, slower path to eradicate the need for a large amount of fuel (and thus a higher cost) on board the spacecraft. After entering the moon's orbit on New Year's Day the probes have been merging their orbits relative to each other. They will begin mapping the moon's gravity from March through to May.



The two GRAIL spacecraft will work in tandem to collect data over an expected 82-day period



Chase
The two spacecraft will follow each other in a near-polar orbit around the moon.

Distance
The distance between them will change as they move over areas of greater and lesser gravity, such as mountains and craters, respectively.

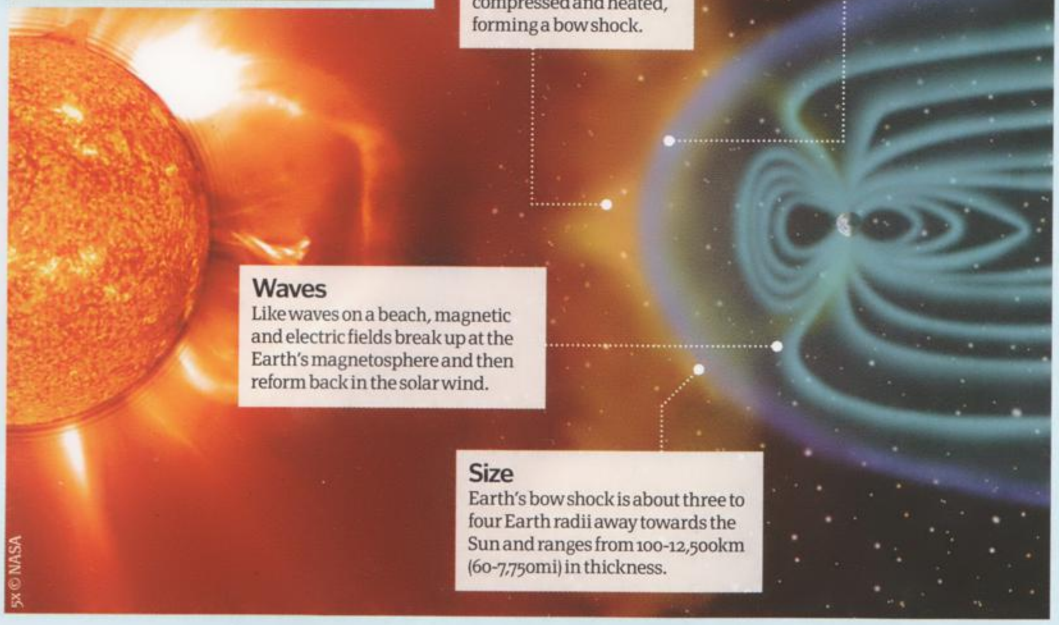
Map
Instruments aboard the spacecraft will accurately measure the changes in their relative velocity, which scientists on Earth will use to create a high-resolution map of the moon's gravitational field.

Separation
Microwave beams are transmitted between the spacecraft to precisely determine the distance between them.

What are bow shocks?

What happens when the solar wind hits Earth?

The red giant star Mira A produces a bow shock 13 light years in length



Bow shock
As the solar wind particles hit Earth's magnetic field they are slowed, compressed and heated, forming a bow shock.

Stock still
The bow shock is totally stationary.

Waves
Like waves on a beach, magnetic and electric fields break up at the Earth's magnetosphere and then reform back in the solar wind.

Size
Earth's bow shock is about three to four Earth radii away towards the Sun and ranges from 100-12,500km (60-7,750mi) in thickness.

5X © NASA

A bow shock is the point at which groups of particles from a source, such as the solar wind, encounter a new medium, such as the magnetic field of a planet. An example would be the point at which the Sun's solar wind abruptly drops as it hits the Earth's magnetosphere. Bow shocks are apparent at every planet in the solar system, but also in other places – for instance, at the edge of the solar system, where the solar wind reaches interstellar space (see 'Voyager shock' above).

So, what exactly is a bow shock? It's basically the point at which particles travelling through space experience an abrupt change in the medium they are passing through, resulting in a sudden decrease in velocity – like the difference between a marble falling through water compared to a jar of treacle. As the solar wind traverses the solar system it is generally unhindered, but when it hits a new medium – such as Earth's magnetic field – it encounters considerable resistance and forms a bow shock as a result.

> "There are five recognised dwarf planets in our solar system – Pluto, Eris, Makemake, Haumea and Ceres"

What makes a puny planet?

Dwarf planets

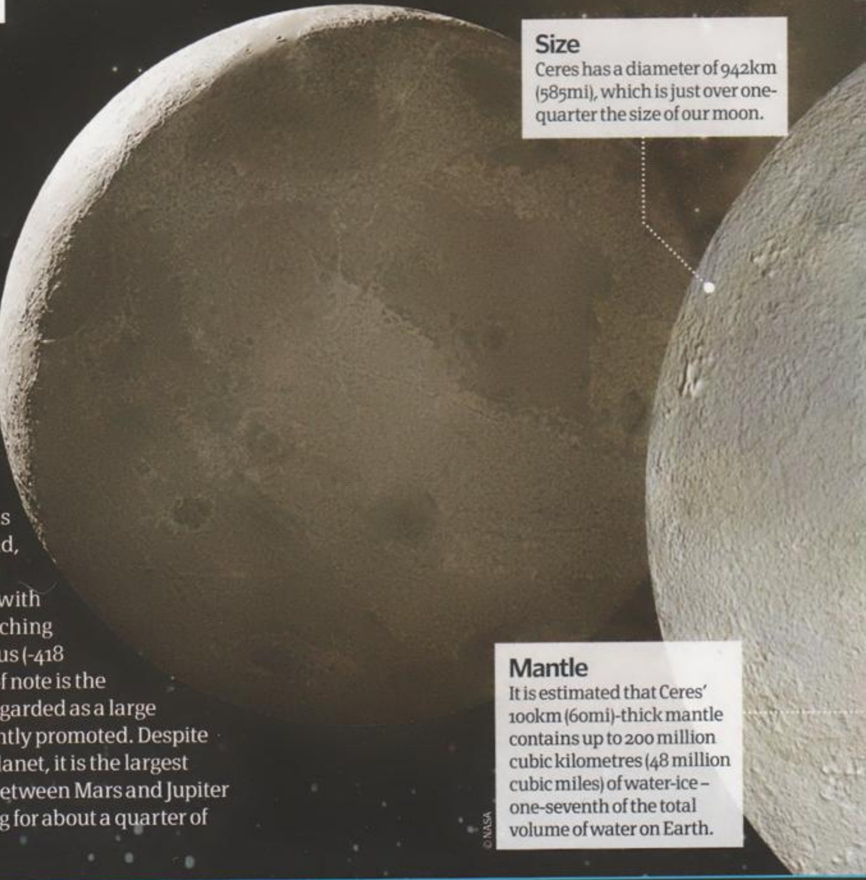
What is a dwarf planet and how is it distinguished from other celestial bodies?

When is a planet not a planet? Well, it's not as simple as you might think. Defining a planet into a particular category isn't easy, with the debate continuing to rage as to how exactly planets should be classified. According to the International Astronomical Union (IAU), dwarf planets are spherical objects in orbit around the Sun that are not moons, but they share their orbits with other debris which they have not been able to clear. It was the latter point that let Pluto down back in 2006, as it has other bodies within its orbit that it has not gathered. In addition, many bodies were discovered that were larger than Pluto, such as Eris, ultimately leading to its reclassification.

In simple terms, a dwarf planet can be regarded as a spherical object in our solar system exhibiting all or some of the properties of a planet, but lacking the necessary gravitational strength to have pulled other local objects into its influence.

There are currently five recognised dwarf planets in our solar system – these being Pluto, Eris, Makemake, Haumea and Ceres – but dozens more in the Kuiper belt, a disc-shaped region beyond Neptune, and the Oort cloud at the outer edge of the solar system, are being considered as candidates.

The five official dwarf planets and their unofficial brothers vary drastically in both composition and appearance, just as the main eight planets of the solar system do. Pluto is the only one of the five known to have its own moon – Charon, while Eris is the coldest of the bunch (and, indeed, the coldest known object in the solar system), with its surface temperature reaching as low as -250 degrees Celsius (-418 degrees Fahrenheit). Also of note is the dwarf planet Ceres, once regarded as a large spherical asteroid but recently promoted. Despite being the smallest dwarf planet, it is the largest object in the asteroid belt between Mars and Jupiter where it resides, accounting for about a quarter of the entire belt's mass. ✲

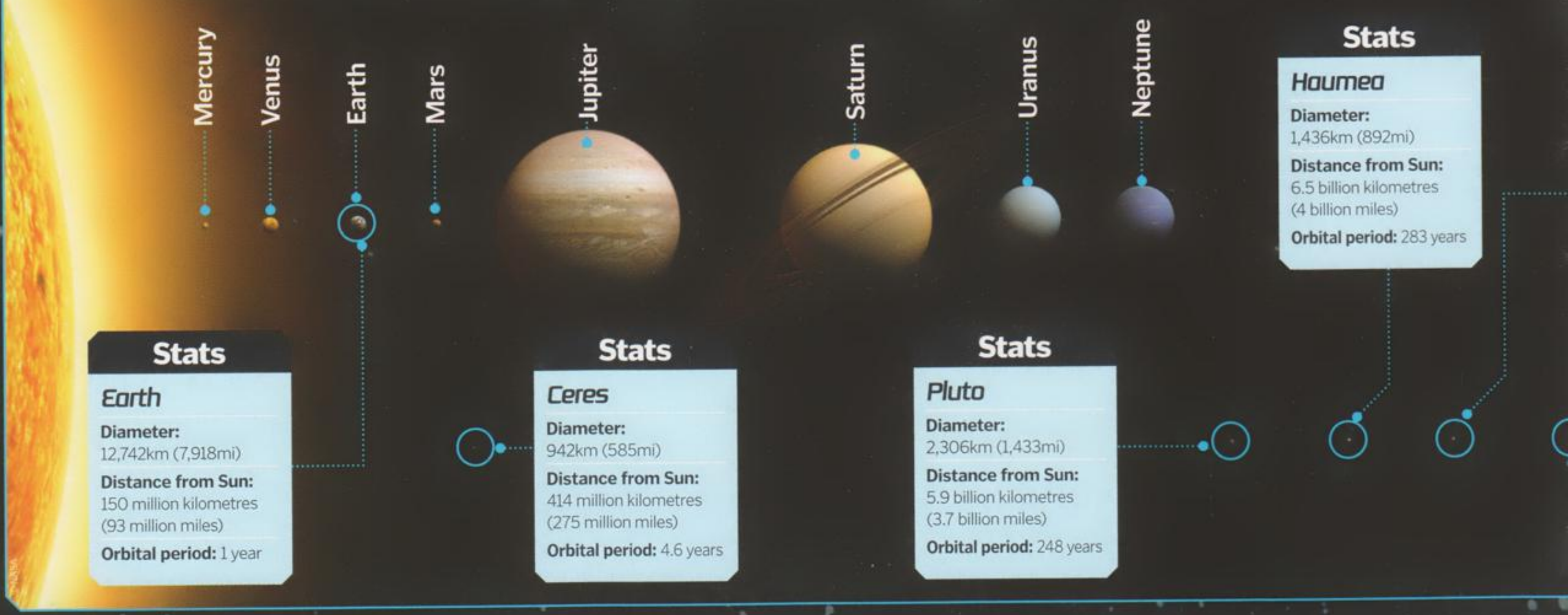


Size
Ceres has a diameter of 942km (585mi), which is just over one-quarter the size of our moon.

Mantle
It is estimated that Ceres' 100km (60mi)-thick mantle contains up to 200 million cubic kilometres (48 million cubic miles) of water-ice – one-seventh of the total volume of water on Earth.

© NASA

How do the dwarf planets size up to Earth?



Stats

Haumea
Diameter: 1,436km (892mi)
Distance from Sun: 6.5 billion kilometres (4 billion miles)
Orbital period: 283 years

Stats

Earth
Diameter: 12,742km (7,918mi)
Distance from Sun: 150 million kilometres (93 million miles)
Orbital period: 1 year

Stats

Ceres
Diameter: 942km (585mi)
Distance from Sun: 414 million kilometres (275 million miles)
Orbital period: 4.6 years

Stats

Pluto
Diameter: 2,306km (1,433mi)
Distance from Sun: 5.9 billion kilometres (3.7 billion miles)
Orbital period: 248 years

Head to Head
THE DWARF PLANETS

© NASA

1. Pluto
Once regarded as the ninth planet of our solar system, Pluto is now classified as a dwarf planet because it lives alongside similar-sized entities in the Kuiper belt.

© Lexicon

2. Eris
The coldest known planetary object in the solar system, the surface temperature on Eris (also found in the Kuiper belt) can drop as low as -250°C (-418°F).

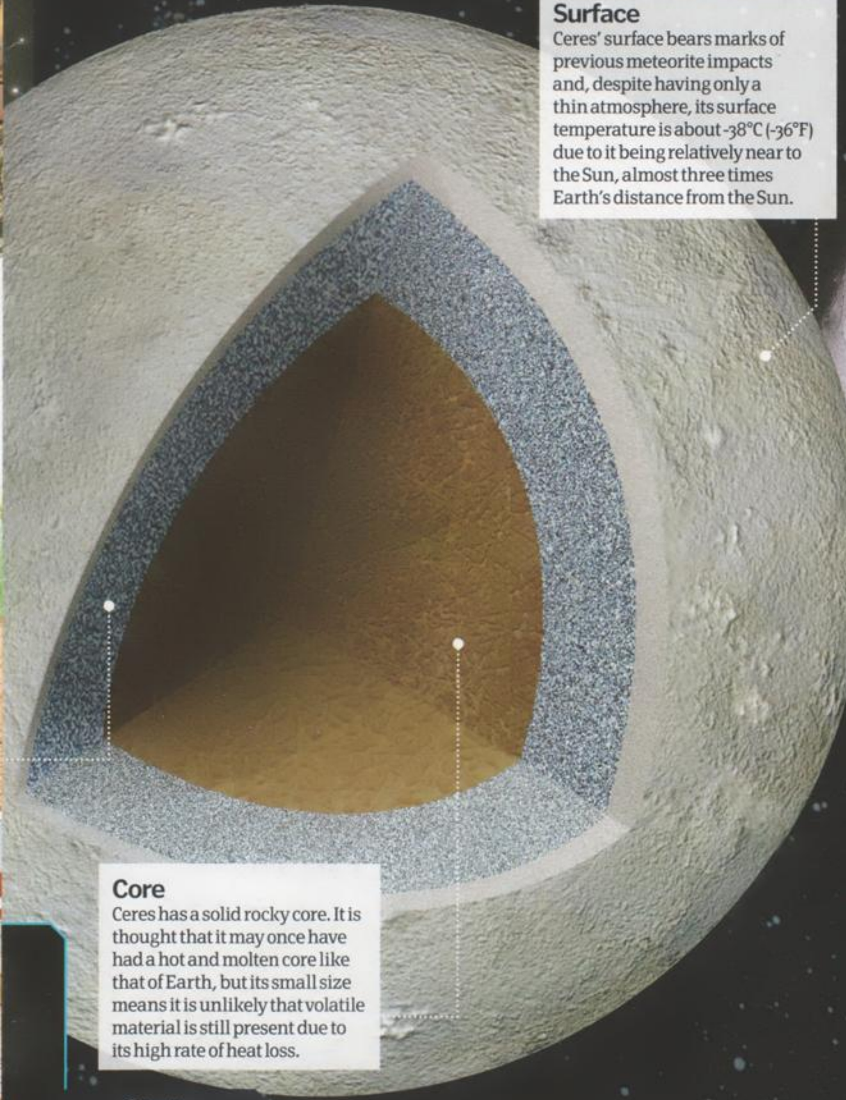
© NASA

3. Ceres
Found in the asteroid belt between Jupiter and Mars, Ceres is the closest dwarf planet to Earth but also the smallest, just one-quarter the size of our moon.

DID YOU KNOW? In December 2011 the first planet smaller than Earth – Kepler-20e – was found outside the solar system

Inside Ceres

What's going on within the smallest dwarf planet in our solar system?



Surface
Ceres' surface bears marks of previous meteorite impacts and, despite having only a thin atmosphere, its surface temperature is about -38°C (-36°F) due to it being relatively near to the Sun, almost three times Earth's distance from the Sun.

Core
Ceres has a solid rocky core. It is thought that it may once have had a hot and molten core like that of Earth, but its small size means it is unlikely that volatile material is still present due to its high rate of heat loss.

© NASA/ESA

© ESO

Stats

Makemake

Diameter: 1,500km (932mi)

Distance from Sun: 6.9 billion kilometres (4.3 billion miles)

Orbital period: 310 years

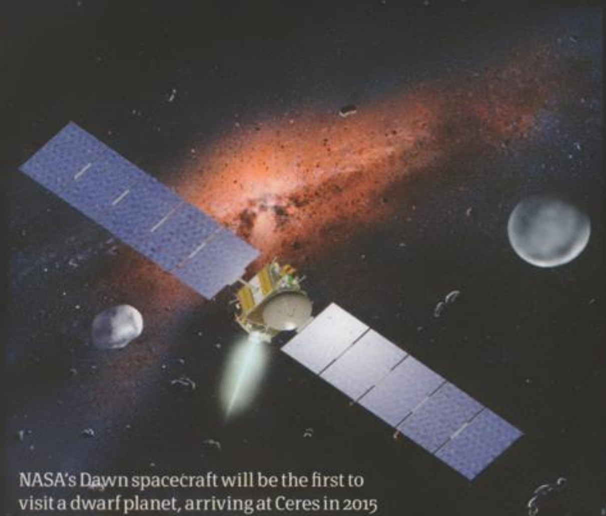
Stats

Eris

Diameter: 2,326km (1,445mi)

Distance from Sun: 10.1 billion kilometres (6.3 billion miles)

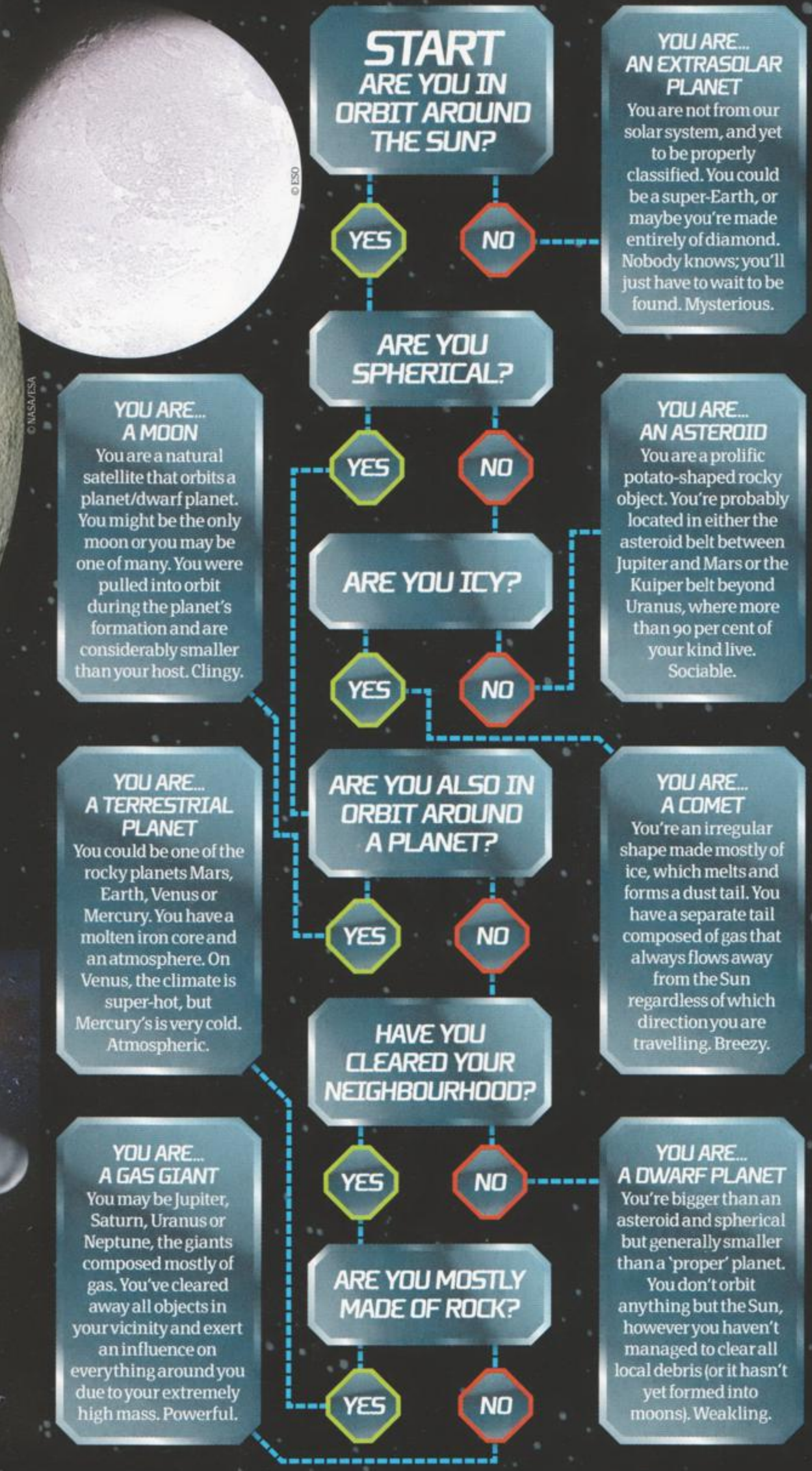
Orbital period: 557 years



NASA's Dawn spacecraft will be the first to visit a dwarf planet, arriving at Ceres in 2015

WHAT TYPE OF PLANET ARE YOU?

Are you a terrestrial planet, a gas giant or a dwarf planet? Or something else? Have a go at our flowchart below to find out…



START
ARE YOU IN ORBIT AROUND THE SUN?
YES
NO

ARE YOU SPHERICAL?
YES
NO

ARE YOU ICY?
YES
NO

ARE YOU ALSO IN ORBIT AROUND A PLANET?
YES
NO

HAVE YOU CLEARED YOUR NEIGHBOURHOOD?
YES
NO

ARE YOU MOSTLY MADE OF ROCK?
YES
NO

YOU ARE… AN EXTRASOLAR PLANET
You are not from our solar system, and yet to be properly classified. You could be a super-Earth, or maybe you're made entirely of diamond. Nobody knows; you'll just have to wait to be found. Mysterious.

YOU ARE… A MOON
You are a natural satellite that orbits a planet/dwarf planet. You might be the only moon or you may be one of many. You were pulled into orbit during the planet's formation and are considerably smaller than your host. Clingy.

YOU ARE… AN ASTEROID
You are a prolific potato-shaped rocky object. You're probably located in either the asteroid belt between Jupiter and Mars or the Kuiper belt beyond Uranus, where more than 90 per cent of your kind live. Sociable.

YOU ARE… A TERRESTRIAL PLANET
You could be one of the rocky planets Mars, Earth, Venus or Mercury. You have a molten iron core and an atmosphere. On Venus, the climate is super-hot, but Mercury's is very cold. Atmospheric.

YOU ARE… A COMET
You're an irregular shape made mostly of ice, which melts and forms a dust tail. You have a separate tail composed of gas that always flows away from the Sun regardless of which direction you are travelling. Breezy.

YOU ARE… A GAS GIANT
You may be Jupiter, Saturn, Uranus or Neptune, the giants composed mostly of gas. You've cleared away all objects in your vicinity and exert an influence on everything around you due to your extremely high mass. Powerful.

YOU ARE… A DWARF PLANET
You're bigger than an asteroid and spherical but generally smaller than a 'proper' planet. You don't orbit anything but the Sun, however you haven't managed to clear all local debris (or it hasn't yet formed into moons). Weakling.

This month in **Environment**

Discover the sleeping giants lying in wait beneath the earth in our supervolcanoes exposé. Will such an eruption occur in our lifetime? What would happen if it did? Where are the world's biggest supervolcanoes? Then take a look at the life of snakes before learning what helps frogs leap such large distances, how mysterious blue holes are formed, why skunks stink, how orchids can survive out of the soil and the anatomical differences between fruit and vegetables.

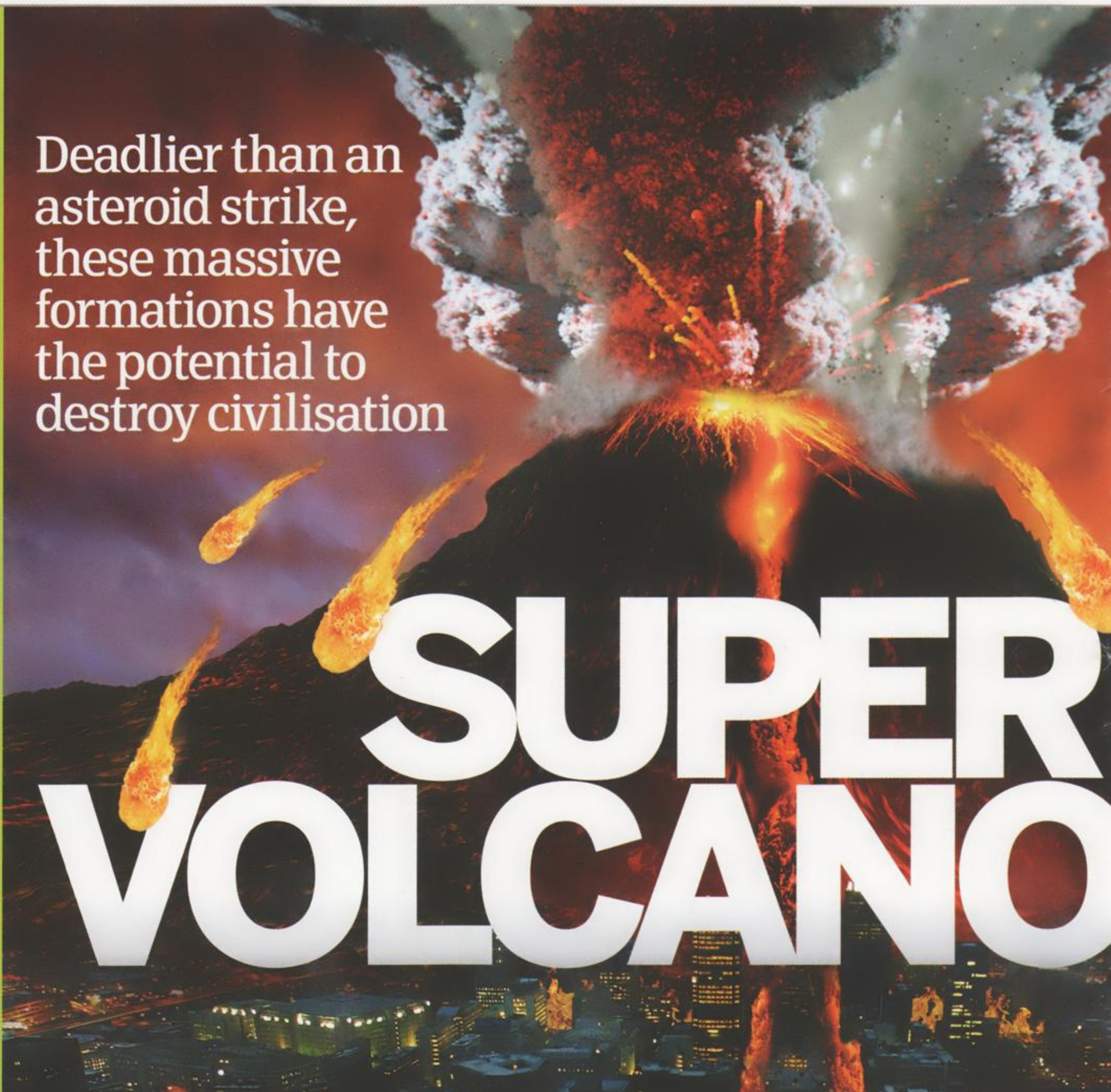
28 Skunks

29 Blue holes

30 Snakes

ENVIRONMENT

22 Supervolcanoes
26 How frogs leap
28 Skunks
28 Orchid anatomy
28 Fruit vs vegetables
29 Blue holes
30 Snakes



Deadlier than an asteroid strike, these massive formations have the potential to destroy civilisation

SUPER VOLCANO

Many people will remember the airport chaos of spring 2010 when Eyjafjallajökull, one of Iceland's largest volcanoes, erupted after almost two centuries of slumber.

But though it might be hard to believe, considering the mammoth amount of disruption that it caused, the Icelandic eruption was tiny compared to a super-eruption's devastating power. The Eyjafjallajökull event measured a mere 4 on the Volcanic Explosivity Index (VEI), which rates the power of eruptions on an eight-point scale. A massive VEI 8 blast, on the other hand, would threaten human civilisation. Such a super-eruption would spew out more than 1,000 cubic kilometres (240 cubic miles) of ejecta – ash, gas and pumice – within days, destroying food crops, and changing the world climate for years.

A super-eruption hasn't happened in recorded history, but they occur about every 10,000-100,000 years. That's five times more often than an asteroid collision big enough to threaten humanity. Scientists say there's no evidence that a super-eruption is imminent, but humans will face nature's ultimate geological catastrophe one day.

A supervolcano is simply a volcano that's had one or more super-eruptions in its lifetime. Supervolcanoes are typically active for millions of years, but wait tens of thousands of years between major eruptions. The longer ▶

5 TOP FACTS SUPERSIZED VOLCANOES

Mysterious

1 Some of Earth's supervolcanoes remain undiscovered. A mystery eruption in Ethiopia, for example, dumped 4,150km^3 (996mi^3) of debris in eastern Africa and the Red Sea.

Mass murderers

2 Some claim the Lake Toba eruption about 74,000 years ago almost drove humans extinct by plunging Earth into a volcanic winter. Only 3,000-10,000 people survived it, they believe.

Made in 2000

3 The word 'supervolcano' was coined in 2000 by BBC science documentary *Horizon*. The word is now used to describe volcanoes that produce gigantic, but rare, eruptions.

Maybe not

4 The odds of a Lake Taupo-sized super-eruption – that is, more than 1,000km^3 (240mi^3) of ash – this century are less than lightning striking your friends and family.

Massive

5 Supervolcano eruptions are dwarfed by Earth's largest lava flow, the Siberian Traps, which flooded an area the size of Australia. Lava erupted here for more than a million years.

DID YOU KNOW? Water heated under Yellowstone causes the park's many geysers

Inside a supervolcano

Hot springs
Snow and rain seep down through fractures in the Earth's crust and are superheated by magma close to the surface.

Caldera
This cauldron-shaped hollow forms when a supervolcano's magma chamber empties during an eruption and the rock roof above collapses.

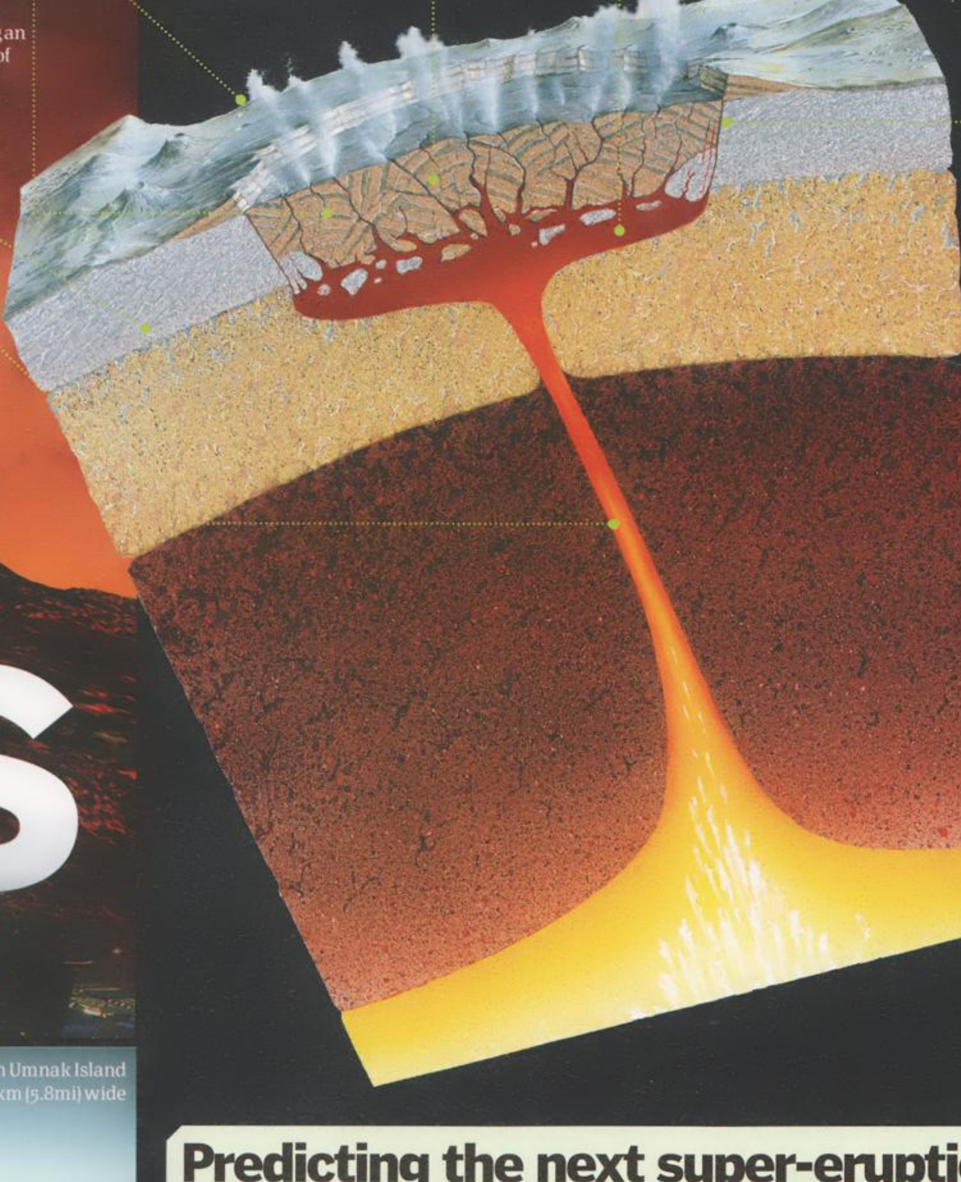
Earth's crust
The Earth's crust is perhaps 56 kilometres (35 miles) thick under the continents and made of solid rock.

Magma
Magma is lighter than the Earth's crust and rises towards the surface where it erupts as a volcano.

Resurgent dome
Molten rock rising in the underground magma chamber pushes the overlying caldera floor upwards into a dome.

Shallow magma chamber
An underground pool of molten rock called magma, which vents to the surface as a volcanic eruption.

Ring fractures
A circular fracture running around the collapsed edge of the magma chamber through which lava often escapes.



© Science Photo Library

8. CALDERA FORMS

DAYS

The rock cylinder inside the ring fractures and plunges into the emptied magma chamber. Gas and lava spurt from the fractures.

7. DEADLY CLOUDS

DAYS

The fractures join into a ring of erupting vents. Toxic ash and fragment clouds race downhill at snow avalanche speed.

6. SUPER-ERUPTION

HOURS TO DAYS

The expanding gases act like bubbles of pop in a shaken bottle, flinging lava and rock high into the atmosphere.

5. MAGMA CHAMBER RUPTURES

HOURS TO DAYS

Vertical fractures in the swollen crust breach the magma chamber, allowing pressurised, gas-filled magma to escape to the surface as lava.

4. WARNING SIGNS INCREASE

WEEKS TO CENTURIES

Warning signs of a super-eruption may include swarms of earthquakes and the ground rapidly swelling up like baking bread.

3. MAGMA CHAMBER EXPANDS

TENS OF THOUSANDS OF YEARS

Supervolcano magma chambers can grow for tens of thousands of years because they are surrounded by flexible hot rock.

2. PRESSURE BUILDS

TENS OF THOUSANDS OF YEARS

As magma accumulates in a chamber, the pressure builds and the cavity expands. Fractures begin to form in the chamber roof.

1. MAGMA RISES

TIME: MILLIONS OF YEARS

Magma forms when rock deep in the Earth liquefies and pushes through the solid crust towards the surface.

COUNTDOWN TO ERUPTION

The Okmok Caldera on Umnak Island in Alaska is 9.3km (5.8mi) wide

Predicting the next super-eruption

Volcanologists at the Yellowstone Volcanic Observatory are among those studying supervolcanoes. They hope to have decades or centuries to prepare for a super-eruption. Warning signs could include the ground bulging and cracking as hot rock muscles to the surface, an increase in small eruptions and earthquakes, and changes in the gases escaping the ground.

Scientists analyse earthquakes by measuring ground vibration with seismometers. Earthquakes often increase before eruptions as magma and gas force through underground fractures, causing rocks to break. The ground historically rises before eruptions due to upwelling magma. For example, the north flank of US volcano Mount St Helens rose by a staggering 80 metres (262 feet) in 1980.

Scientists constantly keep track of Earth movements using networks of satellite GPS receivers. Like GPS in cars, these monitor the receiver's location on the ground. Another satellite technology, InSAR, measures ground movement over large areas once or twice annually.

> "A Yellowstone super-eruption could render one-third of the United States uninhabitable for up to two years"

▶ that they remain dormant, the bigger the super-eruption. They typically erupt from a wide, cauldron-shaped hollow called a caldera, although not every caldera houses a future supervolcano.

The supervolcano simmering under Yellowstone National Park in the USA is probably the world's most studied, but super-eruptions occur so rarely that they remain a mystery. We know of 42 VEI 7 and VEI 8 eruptions in the last 36 million years, but much debris from ancient super-eruptions has worn away. Eruptions like these take place at irregular intervals and scientists are unsure what triggers them.

Supervolcanoes, like all volcanoes, occur where molten or partly molten rock called magma forms and erupts to the Earth's surface. All supervolcanoes break through the thick crust that forms the continents. The Yellowstone caldera sits on a hot spot, a plume of unusually hot rock in the solid layer called the mantle that lies below the Earth's crust. Blobs of molten mantle rise from the hot spot towards the surface and melt the crustal rocks.

Other supervolcanoes like Lake Toba in Sumatra, Indonesia, lie on the edges of the jigsaw of plates that make up the Earth's crust. Near Sumatra, the plate carrying the Indian Ocean is being pushed underneath the crustal plate carrying Europe. As it descends, the ocean plate melts to form magma.

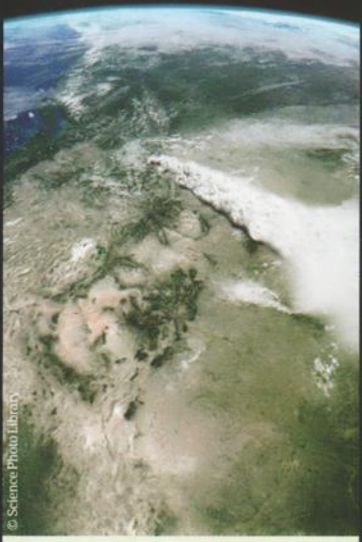
Vast quantities of magma are needed to fuel a super-eruption. Some scientists believe that supervolcanoes are 'super' because they have gigantic, shallow magma chambers that can hold volumes of up to 15,000 cubic kilometres (3,600 cubic miles) and grow for thousands of years. Magma chambers are underground pools of accumulated magma that erupt through cracks to the surface. Volcanoes with smaller chambers expel magma before enough pressure builds for a supersized event.

Some scientists speculate that hot and flexible rocks surround supervolcano magma chambers, allowing them to swell to accommodate more magma. The rocks are kept malleable by blobs of magma repeatedly welling up from below.

A super-eruption starts when the pressurised magma explodes through fractures in the chamber roof. The eruption is violent because supervolcano magma is rich in trapped gas bubbles, which expand and burst as it abruptly depressurises; the eruption is akin to uncorking a champagne bottle. The magma is also sticky and unable to flow easily because it's made partly from melted continental crust. This is in contrast to a volcano like Mauna Loa in Hawaii, which gently pours out lava because its magma is fluid and contains little gas.

Hot fragments and gas soar to heights of more than 35 kilometres (22 miles) and spread in the atmosphere. Some of the fragments drift down and blanket the ground like snow. Other hot fragments rush downhill for hundreds of square kilometres at speeds exceeding 100 kilometres per hour (62 miles per hour) as toxic, ground-hugging pyroclastic flows. The magma chamber rapidly drains during the super-eruption, causing the roof above to sink into the empty space to (re-)form a caldera. ✽

This artist's illustration reveals the smoke and ash that could result from a supervolcanic eruption at Yellowstone



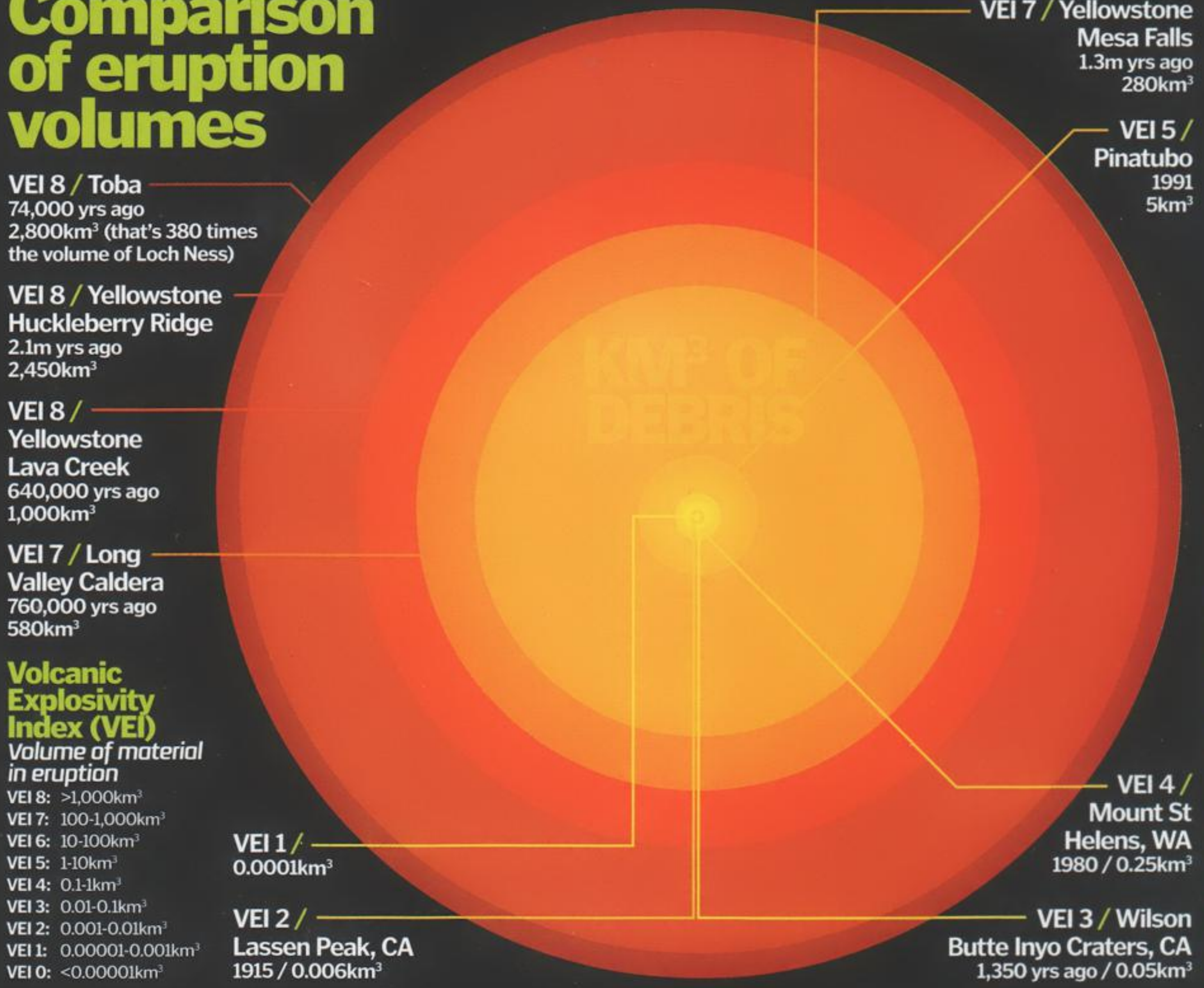
© Science Photo Library

The fallout following a super-eruption

A supervolcano erupting today could threaten human civilisation. Clouds of molten rock and iridescent gas travelling three times faster than motorway cars would obliterate everything within 100 kilometres (60 miles) of the blast. Dust would spread thousands of kilometres, blotting out the Sun. People's unprotected eyes, ears and noses would fill with needle-like ash, which can pop blood vessels in the lungs and kill by suffocation.

Up to 0.5 metres (1.6 feet) of ash could rain down each hour, collapsing roofs, poisoning water supplies and halting transport by clogging car and aircraft engines; just a few centimetres of ash can disrupt agriculture. The 1815 eruption of Indonesia's Mount Tambora caused the 'year without a summer' when European harvests failed, bringing famine and economic collapse. Financial markets could be disrupted and countries swamped by refugees. Some scientists say a Yellowstone super-eruption could render one-third of the United States uninhabitable for up to two years.

Comparison of eruption volumes



Volcanic Explosivity Index (VEI)

Volume of material in eruption

VEI 8:	>1,000km^3
VEI 7:	100-1,000km^3
VEI 6:	10-100km^3
VEI 5:	1-10km^3
VEI 4:	0.1-1km^3
VEI 3:	0.01-0.1km^3
VEI 2:	0.001-0.01km^3
VEI 1:	0.00001-0.001km^3
VEI 0:	<0.00001km^3

Head to Head
SUPERVOLCANO SHOWDOWN

BIG

1. Huckleberry Ridge Caldera
Yellowstone National Park, USA
Yellowstone's biggest eruption 2.1 million years ago blasted a hole in the ground around three times wider than Greater London.

BIGGER

2. Lake Toba
Sumatra, Indonesia
This eruption 74,000 years ago smothered south-east Asia in 15cm (5.9in) of ash and excavated the planet's largest volcanic lake.

BIGGEST

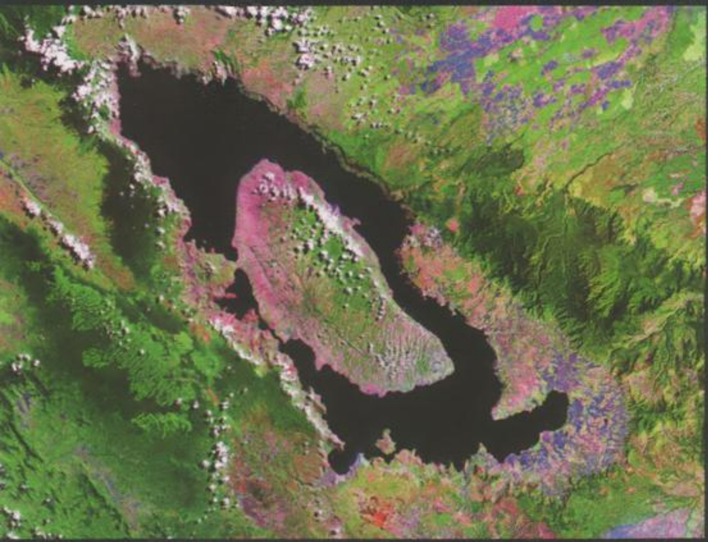
3. La Garita Caldera
Colorado, USA
Earth's biggest known super-eruption, which occurred approximately 28 million years ago, would have buried surrounding states in debris 12m (39ft) deep.

DID YOU KNOW? *Our solar system's most powerful volcano is Loki, which is located on Jupiter's moon Io*

VOLCANOES VS SUPERVOLCANOES
The explosive battle

	TYPICAL VOLCANO	TYPICAL SUPERVOLCANO
FOOTPRINT	Volcanoes vary, but a typical shield volcano might be 5.6km (3.5mi) across. The crater – equivalent to a caldera – of Mount St Helens, USA, is about 3.2km (2mi) wide.	Bigger calderas produce larger eruptions, meaning most supervolcanoes cover vast areas. Lake Toba is 90km (56mi) long and lies in such a caldera.
HEIGHT	Normal volcanoes are cone-shaped mountains perhaps 1km (3,280ft) high. Mount St Helens, for example, stands 635m (2,084ft) above its crater floor.	Supervolcanoes have 'negative' topography: they erupt from smouldering pits. Lake Toba, which lies in a supervolcano caldera, is over 0.5km (0.3mi) deep.
VOLUME	Typical volcanoes have smaller magma chambers. The magma chamber of Mount St Helens, for example, has a volume of just 10-20km^3 (2.4-4.8mi^3).	Yellowstone's magma chamber and caldera are similar in width. The chamber is 60 x 40km (37 x 25mi) wide, and 5-16km (3-10mi) below the surface.
EJECTA	Even huge volcanoes produce comparatively little debris; eg Yellowstone's super-eruptions were up to 2,500 times bigger than the 1980 St Helens blast.	Super-eruptions eject more than 1,000km^3 (240mi^3) of debris. They also spew at least 10^{15}kg (10^{12} tons) of magma: more than the mass of 50 billion cars.
DAMAGE	A few eruptions, like Mt Tambora in 1815, changed global climate, but most of the 20 volcanoes erupting as you read this affect only their immediate vicinity.	A Yellowstone eruption could drop the global average temperature up to 10°C (50°F) for ten years. Within 1,000km (621mi) of the blast, 90 per cent of people could die.

A super-eruption took place in Sumatra 74,000 years ago, forming the planet's largest volcanic lake in the process: Lake Toba



A satellite view of Yellowstone National Park, which is positioned above a hot spot in the Earth's crust

NASA

Geysers like Old Faithful at Yellowstone are heated by the supervolcano which lies beneath

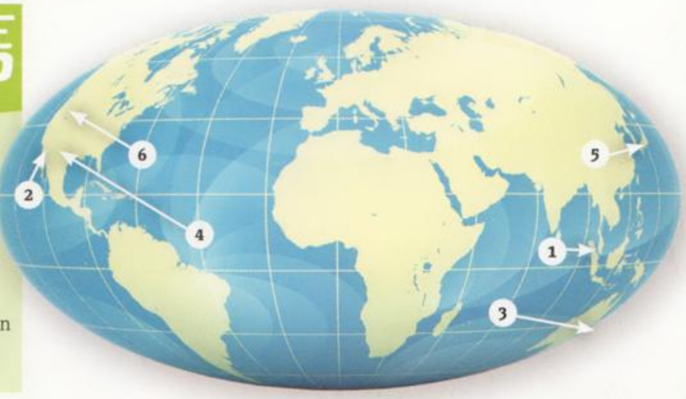
Yellowstone's restless giant

Beneath Yellowstone National Park bubbles an active supervolcano. A magma chamber, lying as close as eight kilometres (five miles) to the surface in places, fuels the park's 10,000 jewel-coloured hot springs, gurgling mud pools, hissing steam vents and famous geysers like Old Faithful. The 8,897-square-kilometre (3,435-square-mile) park includes the volcano's caldera, which spans 4,400 square kilometres (1,750 square miles); that's big enough to cover the emirate of Dubai.

The supervolcano is fuelled by a 'hot spot', a plume of hot rock rising from hundreds of kilometres below the Earth's surface. Hot spots act like gigantic Bunsen burners, driving catastrophic eruptions by melting the rocks above them. Scientists remain uncertain why hot spots form; they're not found at the edge of Earth's crustal plates and most volcanic activity happens where these plates jostle against one another. Since the hot spot formed around 17 million years ago, it has produced perhaps 140 eruptions. The North American crustal plate has slid southwest over the stationary hot spot like a belt on a conveyor leaving a 560-kilometre (350-mile) string of dead calderas and ancient lava flows trailing behind.

There have been three super-eruptions since Yellowstone moved over the hot spot: 2.1 million, 1.3 million and 640,000 years ago. Each eruption vented enough magma from the volcano's storage reservoir to collapse the ground above into a caldera. The first and largest eruption created the Huckleberry Ridge Tuff, more than 2,450 cubic kilometres (588 cubic miles) of volcanic rock made of compacted ash. The eruption blasted a huge caldera perhaps 80 x 65 kilometres (50 x 40 miles) in area and hundreds of metres deep across the boundary of today's national park. The most recent caldera-forming eruption blanketed much of North America in ash and created today's Yellowstone Caldera. Hot gas and ash swept across an area of 7,770 square kilometres (3,000 square miles).

ON THE MAP



Six known supervolcanoes

1. Lake Toba, Sumatra, Indonesia
2. Long Valley, California
3. Lake Taupo, New Zealand
4. Valles Caldera, New Mexico
5. Aira Caldera, southern Japan
6. Yellowstone National Park, United States

"The amphibians feature strong hind legs with specially fused leg bones and big feet"

Elastic energy in the leg muscles transforms into mechanical energy during the leap

How do frogs leap?

Discover what enables this amphibian to jump up to 50 times its own body length

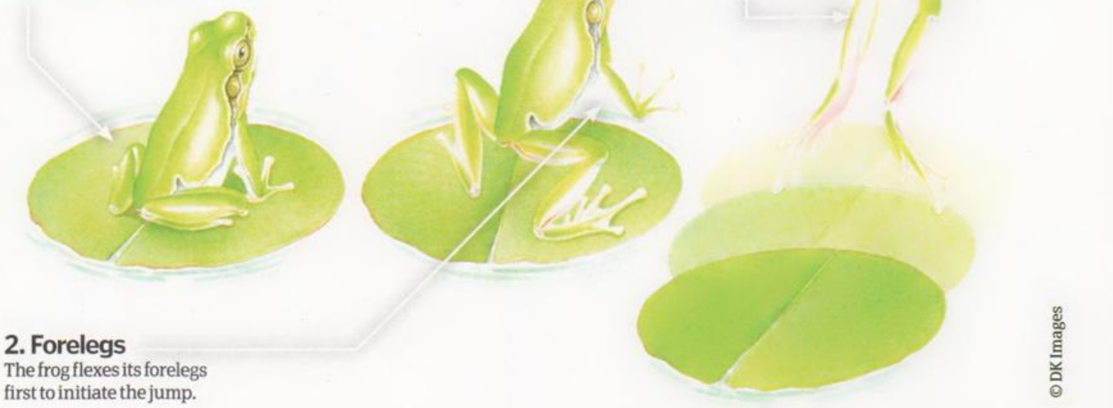
The secret to why frogs can jump so far is all in their legs. The ideal way for a frog to evade predators is to leap away in a split second. The amphibians have evolved extremely strong hind legs with specially fused leg bones and proportionally big feet, which are perfect for launching into the air over huge distances, as they enable the frog to push off against the ground for longer.

Using high-speed cameras to examine the anatomy of a frog as it jumps, researchers have discovered the mechanics of how a frog can travel so far. Pre-jump the muscles in a frog's powerful hind legs are lengthened and stretched as they sit in the typical crouching position. Upon takeoff the muscles connecting the pelvis to the knee contract as the frog flies into the air, pulling the upper hind leg backwards and propelling the frog forwards. The muscles then stretch again once the frog has reached the ultimate height of its jump. These super-stretchy muscles store a huge amount of elastic energy, which in turn is transferred into mechanical energy.

The appropriately named rocket frog can jump a massive two metres (6.6 feet) – that's over 50 times its own body length. This is the equivalent of Olympic triple-jumper Jonathan Edwards jumping around 90 metres (295 feet) in one stride – let alone three.

One mighty leap can be the difference between life and death for a frog

READY FOR TAKEOFF...



1. Stretched and ready
In a crouching position, the super-flexible frog leg muscles are stretched like springs and ready for release.

2. Forelegs
The frog flexes its forelegs first to initiate the jump.

3. Hind legs
Simultaneously the hind legs extend to a vertical position and lock straight at the height of the kick. The thighs then swing round to the side and draw the legs back up into a bent position.

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Fruit versus veg

Which features distinguish fruit from vegetables?

We think of fruit as sweet tasting and vegetables as more savoury in flavour. However, the difference is more scientific than how they taste, and in fact depends on the part of the plant being eaten.

Most plants grow from seeds, which develop inside the female part of the plant, known as the ovary. Once matured, most ovaries develop into fruit, which protects the seeds and promotes dispersal. Fruits are the part of a plant that contains the seeds, and include the likes of melons, oranges and even tomatoes and peppers.

Fruits can be dry or fleshy. Peapods are dry fruits that contain the seeds (peas) inside a casing (pod) for dispersal. Fleshy fruits, also known as drupes, include peaches and raspberries. Drupes are often brightly coloured to attract animals and help spread seeds. Peaches come from a single ovary and feature a seed protected within a hard stone, surrounded by fleshy skin. Despite its name, a raspberry is not a berry at all. While berries are defined as fruit with the seeds and pulp produced from a single ovary, a raspberry is the product of many ovaries, or drupes, clumped together – these are known as drupelets.

The word vegetable is a non-scientific term used to define all the other edible parts of a plant. The other parts that can be eaten include leaves (eg spinach), flowers (eg broccoli), stems (eg celery), roots (eg carrots), tubers (eg potatoes) and bulbs (eg garlic). Of course not all parts of all plants can be eaten as some are poisonous.

Fruit or vegetable?

Lettuce – vegetable (leaves)

Tomato – fruit

Lemon – fruit

Onion – vegetable (bulb)

Pepper – fruit

After an encounter with the spray, the odour can be neutralised via a process called oxidation, which breaks down the thiols into compounds that don't smell

Why does a skunk smell?

Famous for its funky odour, how does this animal's key defensive weapon work?

Despite its small size, the skunk can expertly defend itself against predators, such as bears, that are much larger than itself. There are few things that will deter a predator more than an offensive odour, and the skunk, a small mammal native to North America, is probably most notorious for this ability.

Beneath the skunk's tail are two internal walnut-sized glands that produce a foul-smelling oily spray that can be ejected up to three metres (ten feet). The pungent substance is a thiol, a strong-smelling organic sulphur compound, contact with which can result in a burning or stinging sensation in its victims. While this is not particularly damaging, it is the horrendous stench that is most offputting – it sends out a message to would-be predators that this creature doesn't taste good, so stay away.

Skunks will only release their spray if they feel really threatened as the glands only hold enough of the pungent concoction for five or six strikes and it can take up to ten days to replenish. The animal gives plenty of warning before letting off a stink bomb, including stamping its feet and thrusting its tail high in the air in preparation. When ready to spray, the skunk lifts its tail and extends a tiny protrusion from each gland from which the noxious scent is emitted. Muscles around the glands enable the spray to be projected quickly and with high precision.

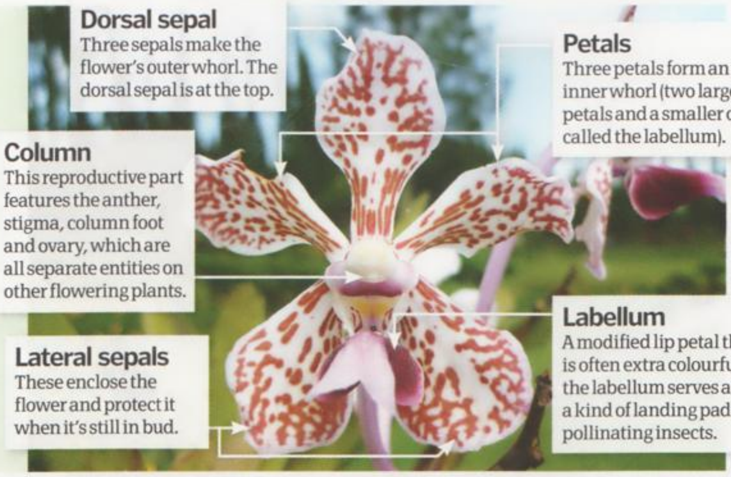
What are orchids?

Discover why they're unlike other flowers

With 25,000 species, the orchid is the largest of the planet's plant families with the most diverse species growing in the tropics and subtropics.

Orchids are found on all continents but Antarctica and can survive pretty much anywhere except true deserts and open water. Orchids grow on the ground using subterranean roots, though some have also developed the ability to grow up trees and other structures using aerial roots.

What sets an orchid apart from most flowering plants, however, is its reproductive anatomy. Orchids have three petals (including one colourful lower petal called the labellum) and three sepals. While on other plants male and female reproductive organs remain separate, on an orchid these parts are fused in a central column.



Dorsal sepal
Three sepals make the flower's outer whorl. The dorsal sepal is at the top.

Petals
Three petals form an inner whorl (two larger petals and a smaller one called the labellum).

Column
This reproductive part features the anther, stigma, column foot and ovary, which are all separate entities on other flowering plants.

Labellum
A modified lip petal that is often extra colourful, the labellum serves as a kind of landing pad for pollinating insects.

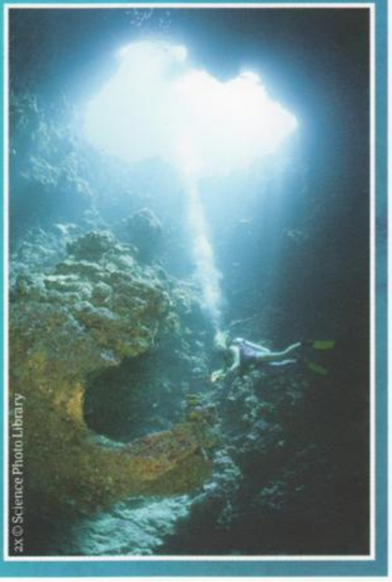
Lateral sepals
These enclose the flower and protect it when it's still in bud.

DID YOU KNOW?

Alien habitat on Earth

The oxygen-free environment of a blue hole results in some of the rarest conditions on Earth. Groups such as NASA are attracted to blue holes to undertake research into the bacterial lifeforms found within. The findings could be indicative of possible ET life on other planets. The lack of oxygen also helps to preserve things like fossilised sea-creatures.

DID YOU KNOW? Some 20 divers who embark on blue hole cave explorations die each year



A scuba diver explores a blue hole in Micronesia

2x © Science Photo Library

How a blue hole forms

Stare into the dark abyss as we explain the creation of these mysterious underwater sinkholes

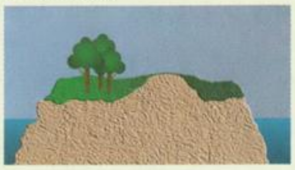
The most abundant examples of these striking geological phenomena are found in and around the islands of the Bahamas. Some 300,000 years ago, when the ice age caused the ice caps to grow and the sea level to fall by up to 120 metres (394 feet), conditions in the Bahamas were well-suited to the formation of underwater caves known as blue holes. A type of karst formation, the blue hole forms as a result of recently exposed soluble rock – such as the limestone uncovered due to a drop in sea level – being eroded by acidic groundwater and rain, which enters through open faults. This causes cavities, caverns and networks of underground tunnels that weaken the structure of the limestone until it collapses in on itself as a sinkhole. When the sea level rises again the entrance to the cave below the surface of the ocean becomes apparent due to the contrast of the deep dark blue of the sinkhole with the lighter shallows of the tropical oceans surrounding it.

One of the most remarkable examples of a blue hole on Earth is the practically perfect circle of the Great Blue Hole off the coast of Belize; at over 300 metres (1,000 feet) across it's also the world's largest. Underwater sinkholes can be as deep as several hundred metres and, due to their hostile conditions, pose an extremely dangerous challenge to even the most experienced divers.

Blue hole formation

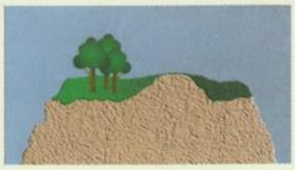
1. Bahamas

Before the ice age the limestone platforms of the Bahamian islands remain intact.



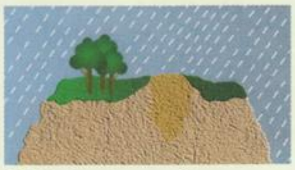
2. Sea level drops

With the onset of the ice age some 300,000 years ago, the sea level drops – by up to 120m (394ft).



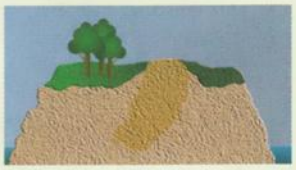
3. Soluble rock exposed

Limestone becomes exposed to the elements, eg rain, which get into any cracks and start to erode the rock.



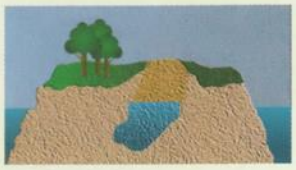
4. Vertical cave forms

Over the course of time the soluble rock is increasingly worn away until eventually a steep, deep-sided vertical cave forms.



5. Sea level rises

With the passing of the ice age, the ice caps begin to melt and sea levels rise once again, refilling the vertical cave with ocean water.



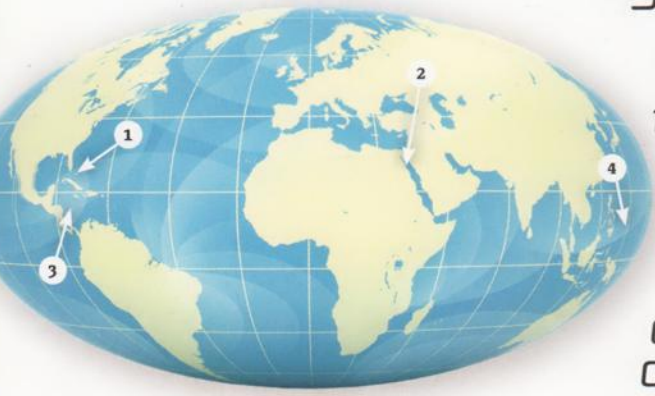
6. Blue hole

A thin layer of less dense freshwater lies over the denser ocean water. If the sea level rises above the height of the opening of the cave an offshore blue hole is visible from above. The dark of the ocean water in the cave is distinct from the shallow coastal waters surrounding it. Inland blue holes are described as those whose entrance is accessible from land.

ON THE MAP

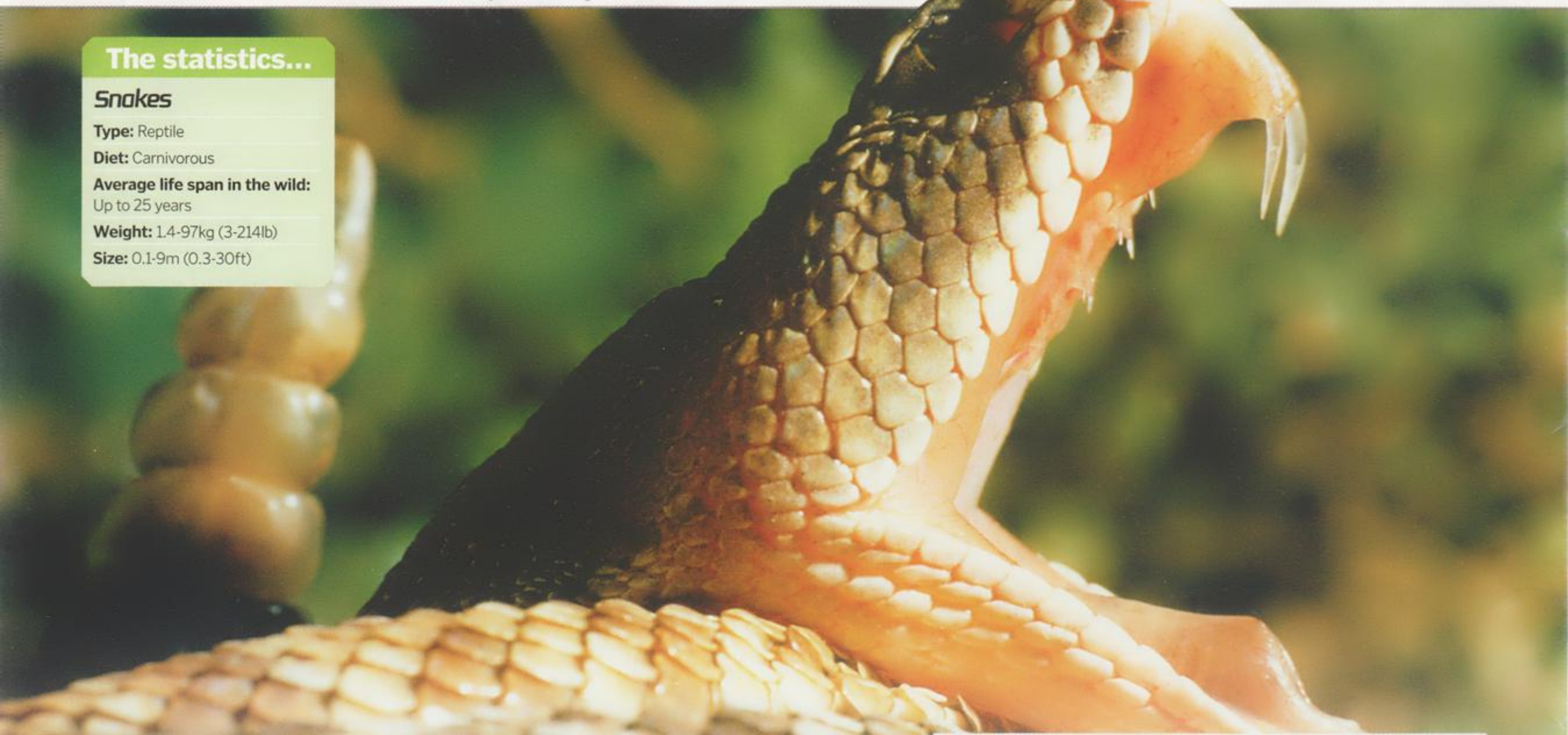
Where in the world can you find blue holes?

1 Bahamas, Atlantic Ocean, Dean's Blue Hole: Deepest
2 Egypt, Red Sea, Blue Hole: Dangerous
3 Belize, Caribbean Sea, Great Blue Hole: Best for diving
4 Guam, Pacific Ocean, Guam Blue Hole: Popular



> "Some 300,000 years ago, conditions in the Bahamas were well-suited to the formation of underwater caves known as blue holes"

"Snakes can sense vibrations through the ground and some species have 'thermal imaging'"



© Photolibrary

The statistics...

Snakes

Type: Reptile

Diet: Carnivorous

Average life span in the wild: Up to 25 years

Weight: 1.4-97kg (3-214lb)

Size: 0.1-9m (0.3-30ft)

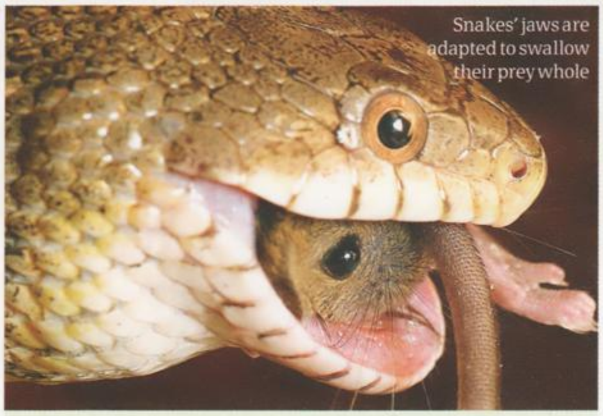
Snakes

Feared and respected in equal measure throughout human civilisation, discover the incredible life of snakes

Snakes are not legless lizards. They evolved from lizards about 112 million years ago but have since changed their body shape and habits quite radically. Modern legless lizards, like the slow worm and grass lizard, have short bodies and long tails, but snakes are nearly all body with a relatively short tail on the end. This means that the skeleton of a snake has ribs running for most of its length. Snakes also lack eyelids and external ear holes. Their eyes are protected by an unblinking, transparent scale called a brille and their poor hearing is made up for by their other senses. Snakes can smell the air by collecting molecules on their forked tongue, then passing them back to the Jacobson's organ at the front of the mouth. They can also sense vibrations through the ground and some species have 'thermal imaging' that enables them to detect the infrared radiation from live prey, even in complete darkness. The coral snake (aipysurus laevis) has light receptors in its tail, so that it can check it hasn't left the tip poking out, when it hides in a dark crevice.

Snakes have scales to conserve moisture and allow them to grip the ground. These aren't loose, like feathers or skin, but are anchored to the deep layers of the epidermis. When a snake moults, it sheds the entire skin in one go. Moulting isn't to allow room for growth (as with insects), but a way of replacing worn scales and getting rid of parasites.

You can find snakes in tropical seas and on every continent except Antarctica, but there are a few islands that they have never conquered, including Iceland, New Zealand and, perhaps most famously, Ireland.



Snakes' jaws are adapted to swallow their prey whole

How snakes hunt

Snakes attack with a fast lunge and a single bite. Their jaws and teeth aren't strong enough to take bites out of their quarry so they must swallow everything whole. Small, non-venomous snakes will strike for the head of a mouse or frog and either try to crush its skull or asphyxiate it by engulfing its mouth and nose.

Venomous species will strike and withdraw to avoid injury while the venom takes effect. Boas and pythons use their muscled bodies to constrict. This doesn't kill by crushing; the coils slide past each other so that the scales act as a ratchet. As the victim struggles, they can only tighten further. Sometimes the prey will die of asphyxiation, other times the pressure in the chest cavity becomes so immense that their heart simply stops.

Snakes don't actually dislocate their jaws to swallow large prey, but the lower jaw is very flexible and has some extra joints at the back of the skull to allow it to 'hinge' open extra wide. The left and right halves of the lower jaw aren't joined and so can 'walk' down an animal, drawing it into the serpent's mouth as they go.

THE STATS
SUPER SERPENTS

LARGEST PREHISTORIC **15m** MOST DEADLY **Indian Cobra** LARGEST PREY **Capybara**

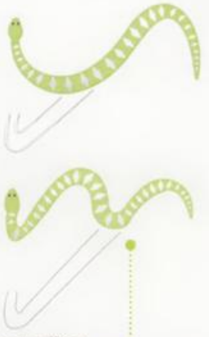
LARGEST VICTIM **Elephant** VENOM DOSE **100-400mg** TOP SPEED **19km/h**

DID YOU KNOW? *Even a severed snake head can still bite and will automatically inject the maximum dose of venom!*

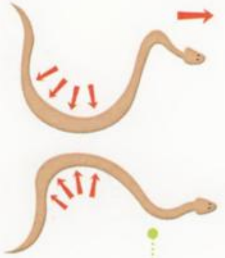
Getting around

With no legs, snakes have developed some clever ways to get from A to B

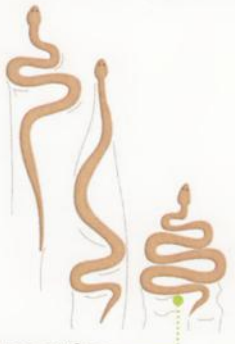
Snakes have many ways of propelling themselves forward, depending on their environment. These use completely different muscle sequences and are much more distinct than, say, the differences between walking and running. All snakes can use lateral undulation but each species has other techniques unique to its habitat. Sea snakes, for example, can use lateral undulation to move backwards, while the chrysopelea snakes of Southeast Asia can even flatten their body into a gliding wing and launch themselves up to 100 metres (328 feet) from one tree branch to another.



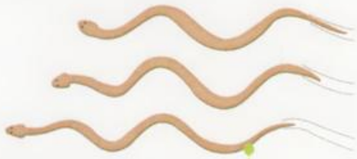
Sidewinding
Sidewinding is an adaptation to loose or slippery surfaces, so the contact points between the snake and the ground don't slide backwards. This maximises grip and uses less than one-third of the energy of a lizard which is running the same distance.



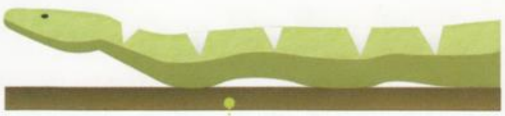
Slide pushing
In tunnels, there's no room to move side to side, so the snake alternately braces against the tunnel walls and stretches its body forwards. It's slower than lateral undulation and uses seven times more energy, but it's still faster than rectilinear movement.



Concertina
The snake pulls its body into a tight series of coils and then braces the tail section as it straightens out again. This needs good grip or something to push against, and it isn't efficient for long distances, but it's a quick way to lunge forward when striking.

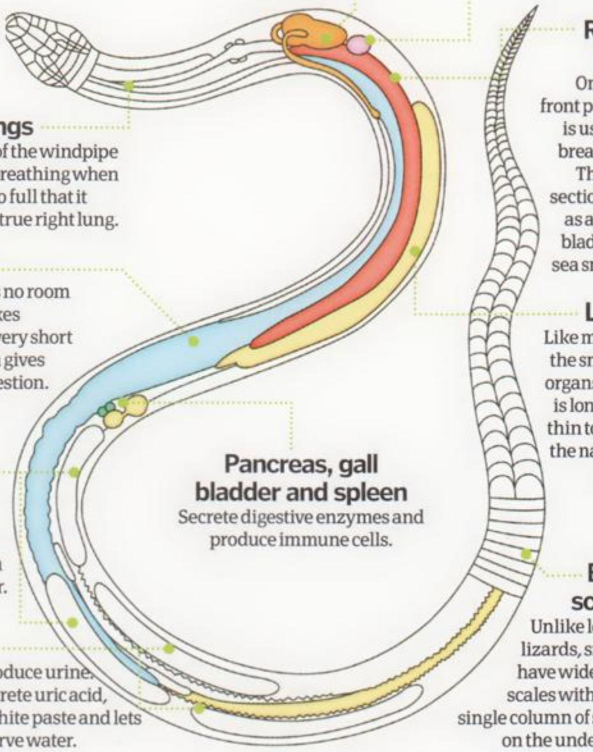


Lateral undulation
The most common form of locomotion involves the snake gripping obstructions or small irregularities on the ground with the side of its body, and rippling a wave down their length that slides past the obstruction. Aquatic snakes swim like this by pushing against the water itself.



Rectilinear
The slowest way to move uses the tiny muscles that attach the skin to the ribs. By alternately pulling the skin up off the ground and putting it down again slightly forward, the snake creates a travelling wave that creeps it forward almost silently. This form of movement is employed by pythons and boas when stalking prey.

The anatomy of a snake



Heart
Snakes have no diaphragm, so the heart is free to move out of the way when swallowing large prey.

Left lung
Shrunk to almost nothing to save space, the left lung isn't used for breathing.

Right lung
Only the front portion is used for breathing. The rear section acts as a swim bladder in sea snakes.

Tracheal lungs
This extension of the windpipe allows limited breathing when the stomach is so full that it compresses the true right lung.

Intestine
Because there is no room to coil it up, snakes actually have a very short intestine, which gives them a slow digestion.

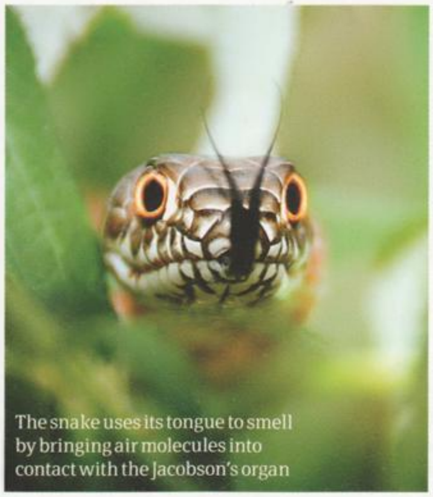
Liver
Like most of the snake's organs, this is long and thin to fit in the narrow body.

Pancreas, gall bladder and spleen
Secrete digestive enzymes and produce immune cells.

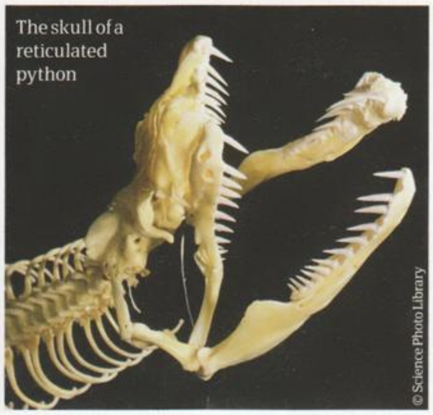
Testes
Where snakes retain paired organs, they are staggered one in front of the other.

Kidneys
Snakes don't produce urine. Instead they excrete uric acid, which is a dry white paste and lets the snake conserve water.

Belly scales
Unlike legless lizards, snakes have wide belly scales with just a single column of scales on the underside.



The snake uses its tongue to smell by bringing air molecules into contact with the Jacobson's organ



The skull of a reticulated python

© Science Photo Library

A deadly cocktail

There are 2,900 species of snake but only a quarter of them are venomous. Out of those, 250 species are deadly enough to kill a human with one bite and around 100,000 people are killed by snakebites worldwide each year.

Snake venom is produced in modified salivary glands and stored in reservoirs behind the eyes. Snakes can choose the dose they deliver with each bite and will sometimes 'dry bite' without injecting at all. Each species has a different venom that is a mixture of hundreds or thousands of different proteins and enzymes. Between them, they can affect every organ system in the body if left unchecked.

MAIN SYMPTOMS

- Rubbery, minty or metallic taste in the mouth
- Fear and panic
- Vomiting
- Diarrhoea
- Dizziness and fainting
- Severe pain
- Blurred vision
- Convulsions
- Rapid, weak pulse
- Spontaneous bleeding
- Numbness
- Breathing difficulty
- Tissue necrosis
- Heart failure

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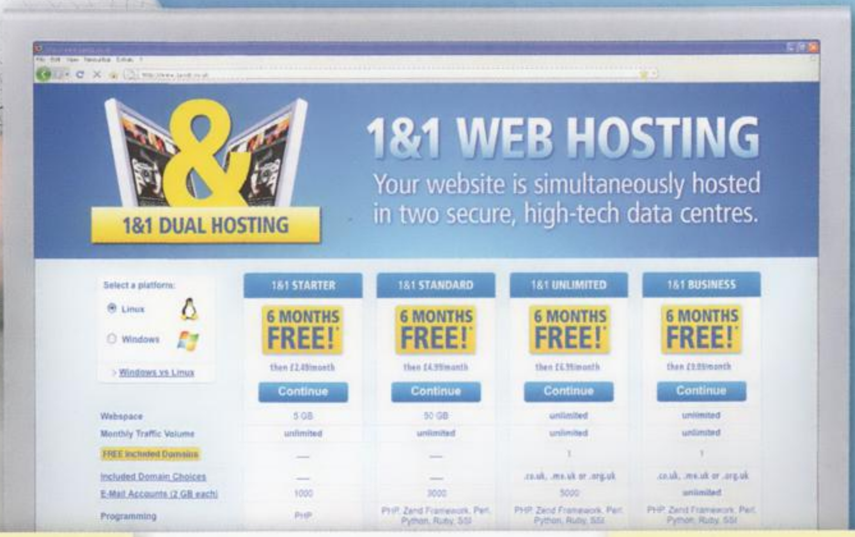

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Webspace	5 GB	50 GB	unlimited	unlimited
Monthly Traffic Volume	unlimited	unlimited	unlimited	unlimited
FREE Included Domains	—	—	1	1
Included Domain Choices	—	—	.co.uk, .me.uk or .org.uk	.co.uk, .me.uk or .org.uk
E-Mail Accounts (2 GB each)	1000	3000	5000	unlimited
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This month in Technology

Together with a look at what's inside the much-anticipated Galaxy Nexus phone, you can also explore the next generation of robotic engineering in our big feature on page 44. Not only that but you'll also learn about how braces straighten crooked teeth and loads more cool gadgets.

36 Dental braces

it's dad's birthday

Here's your reminder for May 19, 2012 at 9 am:

19 Saturday May 2012

Dad's birthday

Cancel

Confirm

38 Siri

39 Analogue alarm clocks

TECHNOLOGY

34 Samsung Galaxy Nexus
36 Snow cannons
36 Dental braces
37 Bowling machines
38 Siri
39 Tattoo guns
39 Analogue alarm clocks
40 Paper production
42 Chocolate fountains
42 Air purifiers
44 Next-gen robots

Samsung Galaxy Nexus

Google's new flagship smartphone, with the cutting-edge Ice Cream Sandwich OS, is being touted as the best phone ever made, but how does it work?

The Galaxy Nexus is equipped with an in-built gyro, compass, barometer and accelerometer

© Samsung

Key to how the Samsung Galaxy Nexus works in comparison with other high-end Android smartphones is its implementation of the Android 4.0 operating system codenamed Ice Cream Sandwich (ICS). There are plenty of other superfast Android phones on the market right now but none, excluding the Galaxy Nexus, are running the new OS, which is a radical departure from how traditional Android operating systems look and work. Crucially, many of the standout changes delivered by ICS – and, as such, the Galaxy Nexus – are system-wide making for a comprehensively updated phone.

The base of almost all of ICS's improvements stem from its unified user interface framework. This unification of framework draws together all Android hardware from here on – be that tablet or phone – and offers all of the traditional Android 3.x interface elements such as application programming interface fragments, content loaders, action bars, notifications and dynamic widgets, as well as a selection of next-generation features that drastically alter how the hardware is interacted with.

The first, if not foremost, of these features, is the heavy integration of gestures into Android 4.0. These allow a variety of finger gestures to access and dismiss applications and notifications, as well as core programs and functions. As such, users can now open and close tabs by simply swiping their finger across the screen, rather than indirectly doing so by an in-browser menu. Further, many of these gestures remain active throughout the OS, allowing, for example, notifications and music playback options to be directly accessed via the lock screen. Another good example of this also stems from the lock screen, where incoming calls can be responded to via text message by simply gesturing to a pre-set response list. This gesture-heavy functionality even extends to setup, where by drawing a clockwise square on the screen, users can activate the explore-by-touch mode, which enables them to navigate the phone without even seeing the screen.

Communication and sharing options are also integrated across the 4.0 system. Throughout ICS, user profiles, social groups and contacts are now linked and augmented with system-level social-networking information. A good example of this can be seen in the Galaxy Nexus's new People app. This is a direct replacement of the former Android OS Contacts app that delivers deeper profile information than before but also status, photo and event information for each contact, derived from any social network they may be using. Further, gesture-driven shortcuts to phone numbers, text messages and email addresses allow for faster and more fluid accessibility.

5 TOP FACTS GALAXY NEXUS

Announced

1 The Galaxy Nexus was officially unveiled on 19 October 2011 in Hong Kong at Google and Samsung's Ice Cream Sandwich event. The handset then went on sale on 17 November.

Linked

2 The Galaxy Nexus features MHL (mobile high-definition link) tech. This allows it to output 1080p audio-visual content via its microUSB 2.0 port to any external display via HDMI.

Hanging out

3 It comes installed with support for Google+ Hangouts, a feature where you can let your friends know you're free and then video chat with up to ten of them at the same time.

Unlocked

4 The Galaxy Nexus introduces a new way to unlock your phone. Thanks to state-of-the-art facial-recognition tech, your own face can become the key. Bye bye, passwords.

Curved

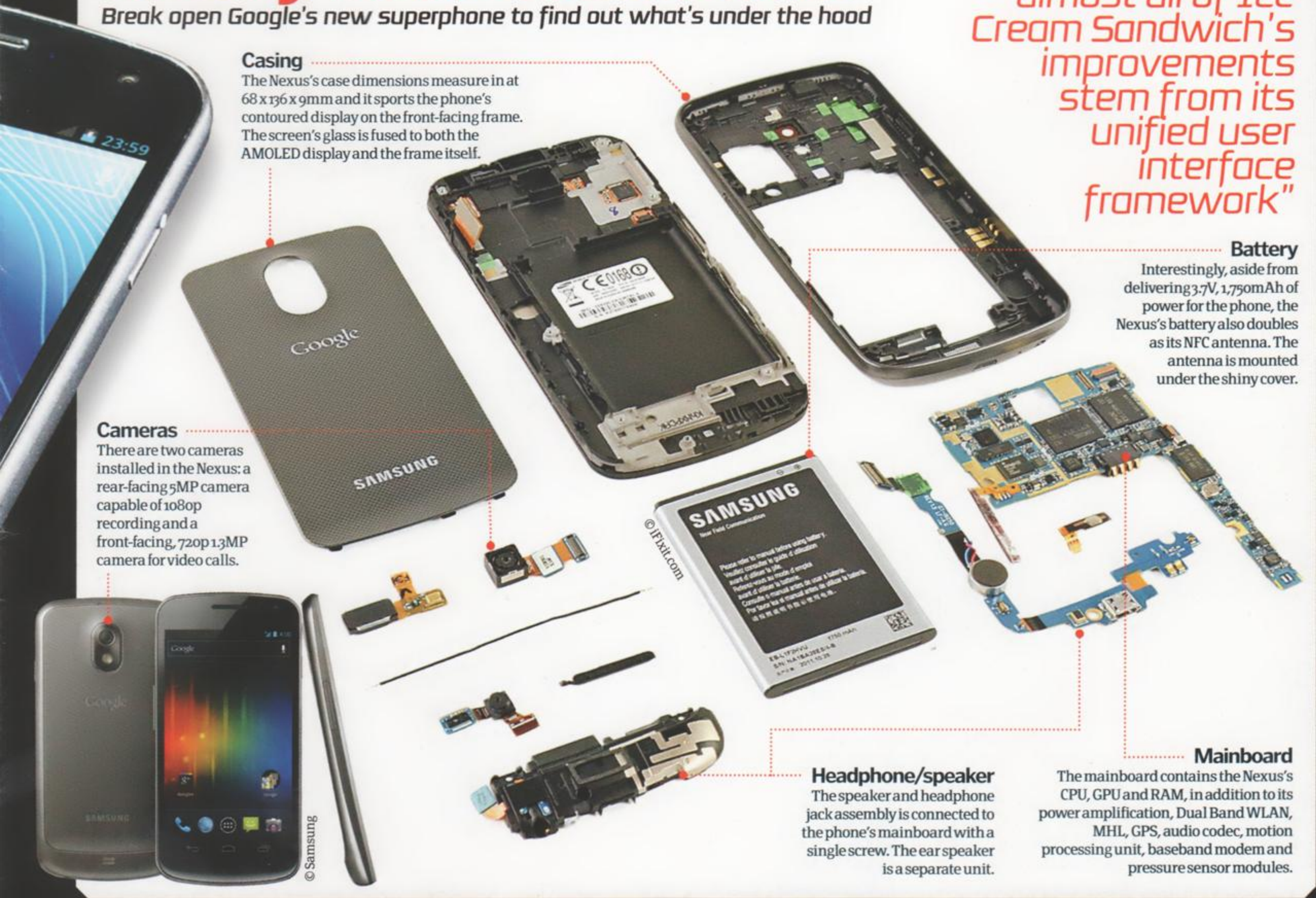
5 Despite its flat appearance, the 4.65-inch AMOLED screen is in fact curved ever so slightly (1mm/0.04in) at the deepest point), following the path of the tapered top and bottom.

DID YOU KNOW? Google delayed the reveal of the Galaxy Nexus in light of Steve Jobs' passing

Galaxy Nexus teardown

Break open Google's new superphone to find out what's under the hood

> "The base of almost all of Ice Cream Sandwich's improvements stem from its unified user interface framework"



© iFixit.com

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Casing
The Nexus's case dimensions measure in at 68 x 136 x 9mm and it sports the phone's contoured display on the front-facing frame. The screen's glass is fused to both the AMOLED display and the frame itself.

Cameras
There are two cameras installed in the Nexus: a rear-facing 5MP camera capable of 1080p recording and a front-facing, 720p 1.3MP camera for video calls.

Battery
Interestingly, aside from delivering 3.7V, 1,750mAh of power for the phone, the Nexus's battery also doubles as its NFC antenna. The antenna is mounted under the shiny cover.

Headphone/speaker
The speaker and headphone jack assembly is connected to the phone's mainboard with a single screw. The ear speaker is a separate unit.

Mainboard
The mainboard contains the Nexus's CPU, GPU and RAM, in addition to its power amplification, Dual Band WLAN, MHL, GPS, audio codec, motion processing unit, baseband modem and pressure sensor modules.

Lastly, ICS delivers deeply integrated near-field communication (NFC) tech to the Galaxy Nexus, allowing two NFC-enabled devices to share webpages, contacts, videos, apps and more simply by touching them together. NFC works through radio-frequency identification standards (RFID) to generate passive or active gateways through which information can be transmitted over short distances between two endpoints (ie handsets). This form of data transfer, which does require a telecoms network or Wi-Fi, promises to transform how users share information and even pay for goods and services. This is epitomised in recent services such as Google Wallet, which allows Galaxy Nexus owners to pay for items by simply touching their handset to a payment terminal. ✿

ANDROID TOP TRUMPS *THERE CAN BE ONLY ONE... KING OF ANDROID!*

	GALAXY NEXUS	GALAXY S II	NEXUS S 4G
CPU	1.2GHz dual-core processor	1.2GHz dual-core processor	1.0GHz single-core processor
GPU	384MHz PowerVR SGX540	ARM Mali-400 MP	384MHz PowerVR SGX540
MEMORY	1GB RAM	1GB RAM	512MB RAM
STORAGE	16/32GB internal storage	16/32/64GB internal storage	16GB internal storage
SCREEN	4.65-inch Super AMOLED display	4.3-inch Super AMOLED Plus display	4.0-inch Super AMOLED display
CAMERA	5MP, 1080p, rear-facing camera	8MP, 1080p, rear-facing camera	5MP, 2,560 x 1,920, rear-facing camera
BATTERY	1,750mAh	1,650mAh	1,500mAh
WEIGHT	135g (4.8oz) LTE	116g (4.1oz)	131g (4.6oz)
CONNECTIVITY	Wi-Fi, near-field communication (NFC), GPS, Bluetooth 3.0	Wi-Fi, near-field communication (NFC), GPS, Bluetooth 3.0	Wi-Fi, near-field communication (NFC), A-GPS, Bluetooth 2.1
OS	Android 4.0 Ice Cream Sandwich	Android 2.3.5 Gingerbread	Android 2.3.6 Gingerbread

VS

VS

> "The brace consists of a number of metal brackets and wires affixed to the front of each tooth"

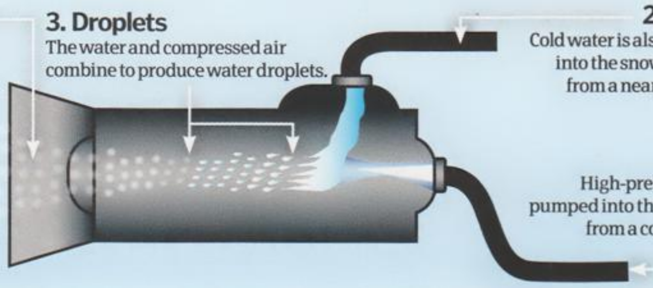
Snow machines are used to replenish slopes that are lacking natural powder

Snow machines

How do these devices produce manmade snow?

Snow machines are used on both indoor and outdoor ski slopes around the world to provide additional snow when the real stuff is lacking. The material they create is actually snow, but the process by which it is made is a little different to the natural system. Snow that forms as nature intended in clouds is basically frozen crystals of water, and the same is true of snow guns.

However, these devices have to create a cold environment in which they can produce snow, simulating the conditions in clouds. Most snow cannons do this in a relatively simple process, combining cold water and compressed air to produce water droplets. The guns are connected to a supply of water and high-pressure air, which are both pumped into the machine. The droplets then freeze into ice crystals inside the machine and, when fired out by a fan, fall as snow. Most machines lack the ability to change their firing direction (like a sprinkler), so ploughs and other vehicles are used to spread the fresh powder across the slopes.



4. Freeze
The water droplets then form into ice crystals, or snow, inside the gun.

5. Snow
The snow is often fired upwards out of the machine so that it remains frozen before it hits the ground.

3. Droplets
The water and compressed air combine to produce water droplets.

2. Water
Cold water is also pumped into the snow machine from a nearby source.

1. Air
High-pressure air is pumped into the machine from a compressor.

Orthodontic braces explained

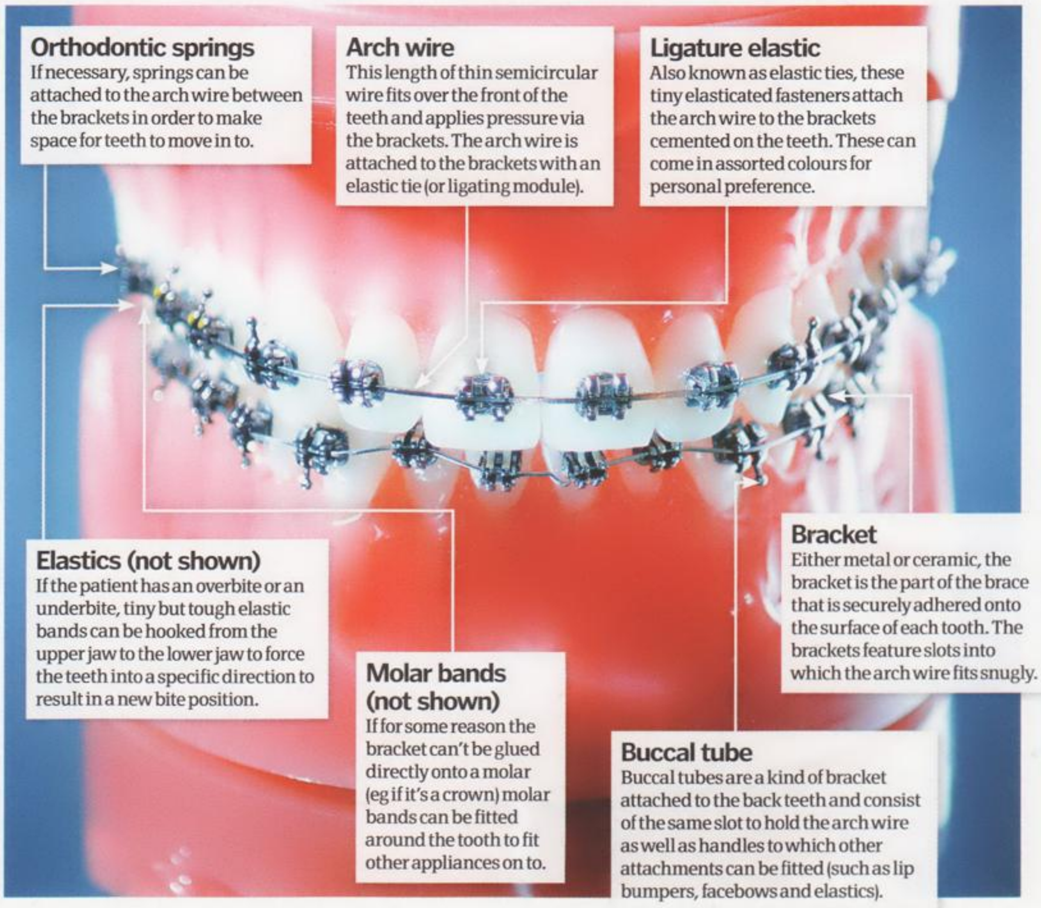
How these metal frames correct the position of misaligned teeth

The literal translation of 'orthodontics' is 'to straighten teeth'. Traditional fixed orthodontic braces can correct crooked teeth, those damaged through injury, or dental abnormalities such as malocclusions or overcrowding. The device consists of a number of metal brackets and wires affixed to the front of each tooth, which then puts sustained pressure on the dentures, gradually moving them into the correct position for a natural or more comfortable bite.

The wires (arch wires) are a type of shape memory metal made from an alloy of titanium and nickel with copper or aluminium. While memory metal is quite malleable at room temperature, it really wants to retain its original shape. When warmed up by heat from the mouth (around 20 degrees Celsius/68 degrees Fahrenheit higher than room temperature) the memory metal is activated. It then stiffens and takes on its original form, which presses against the teeth.

Beneath the gum tissue is a layer of collagen fibres known as the periodontal ligaments, which bind the tooth roots to the sockets of the alveolar bone in the jaw. When pressure is put on the tooth, the periodontal membrane will stretch on one side but compress on the other. This loosens the tooth and causes the bone to regrow to support it.

While a tooth under pressure will begin to move after about 72 hours, the bone will not be fully formed for up to three months. So even after a fixed brace has relocated the teeth they must remain supported to enable the bone to fill in. To keep the teeth set in position, a removable retainer can be worn, ensuring teeth don't return to their original crooked position.



Orthodontic springs
If necessary, springs can be attached to the arch wire between the brackets in order to make space for teeth to move in to.

Arch wire
This length of thin semicircular wire fits over the front of the teeth and applies pressure via the brackets. The arch wire is attached to the brackets with an elastic tie (or ligating module).

Ligature elastic
Also known as elastic ties, these tiny elasticated fasteners attach the arch wire to the brackets cemented on the teeth. These can come in assorted colours for personal preference.

Elastics (not shown)
If the patient has an overbite or an underbite, tiny but tough elastic bands can be hooked from the upper jaw to the lower jaw to force the teeth into a specific direction to result in a new bite position.

Molar bands (not shown)
If for some reason the bracket can't be glued directly onto a molar (eg if it's a crown) molar bands can be fitted around the tooth to fit other appliances on to.

Bracket
Either metal or ceramic, the bracket is the part of the brace that is securely adhered onto the surface of each tooth. The brackets feature slots into which the arch wire fits snugly.

Buccal tube
Buccal tubes are a kind of bracket attached to the back teeth and consist of the same slot to hold the arch wire as well as handles to which other attachments can be fitted (such as lip bumpers, facebows and elastics).

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DID YOU KNOW? The England cricket team use programmable bowling machines to train before series

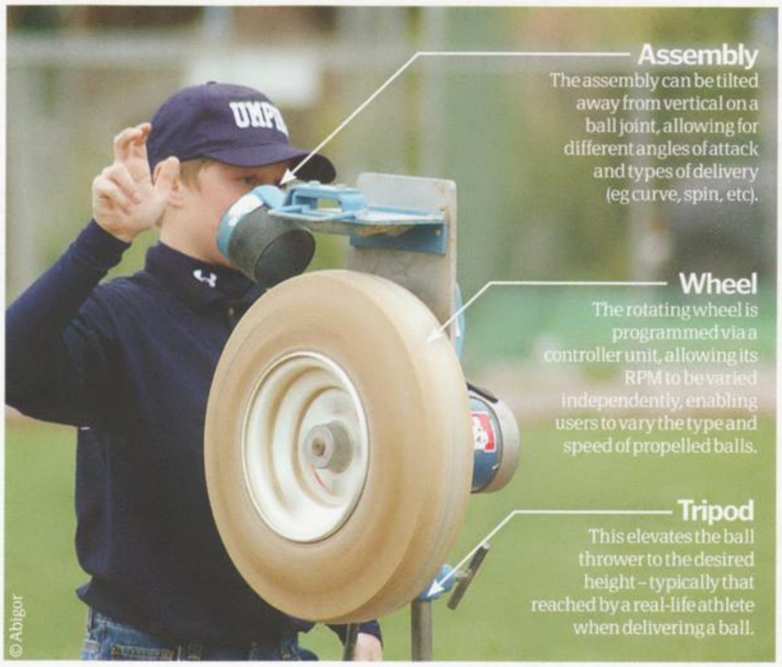
Ball-throwing machines explained

How do these versatile training devices replicate a human sports opponent?

Ball-throwing machines – commonly referred to as bowling or pitching machines – are used in many sports worldwide, ranging from hockey to baseball and cricket, so that athletes can practise regardless of team numbers. They are designed to propel a ball towards a target at a specific speed and elevation, as well as with other desired effects, such as spin, that are commonly experienced during a competitive sporting event.

The projection mechanism of a typical bowling machine comprises two 30-50-centimetre (12-20-inch) steel wheels (though one-wheeled systems do exist, as pictured), each lined with a rubberised, scored coating. Each of the wheels is powered by an independent electric motor, which in turn are rotated by a portable 12-volt battery or via mains electricity. Both wheels are mounted on the same plane (either vertically or horizontally) within a composite metal and plastic frame, roughly seven centimetres (three inches) apart. Once powered, the wheels rotate at a high speed. When automatically fed with special balls (typically replicating those of a certain sport such as a baseball) from the rear of the assembly, thanks to the gripping friction generated upon contact with the scored tyres, they are projected forwards at high velocity.

That all-important spin and curve is achieved by a ball-throwing machine by varying the speed, angle of release and the direction of wheel rotation. For example, to achieve spin on a projected ball, a bowling machine is commonly tilted to one side (on a ball joint) and its wheels programmed to spin at two markedly different rotations-per-minute (RPM), thereby applying a degree of spin to the ball as it is forced out of the contraption.



Assembly
The assembly can be tilted away from vertical on a ball joint, allowing for different angles of attack and types of delivery (eg curve, spin, etc).

Wheel
The rotating wheel is programmed via a controller unit, allowing its RPM to be varied independently, enabling users to vary the type and speed of propelled balls.

Tripod
This elevates the ball thrower to the desired height – typically that reached by a real-life athlete when delivering a ball.

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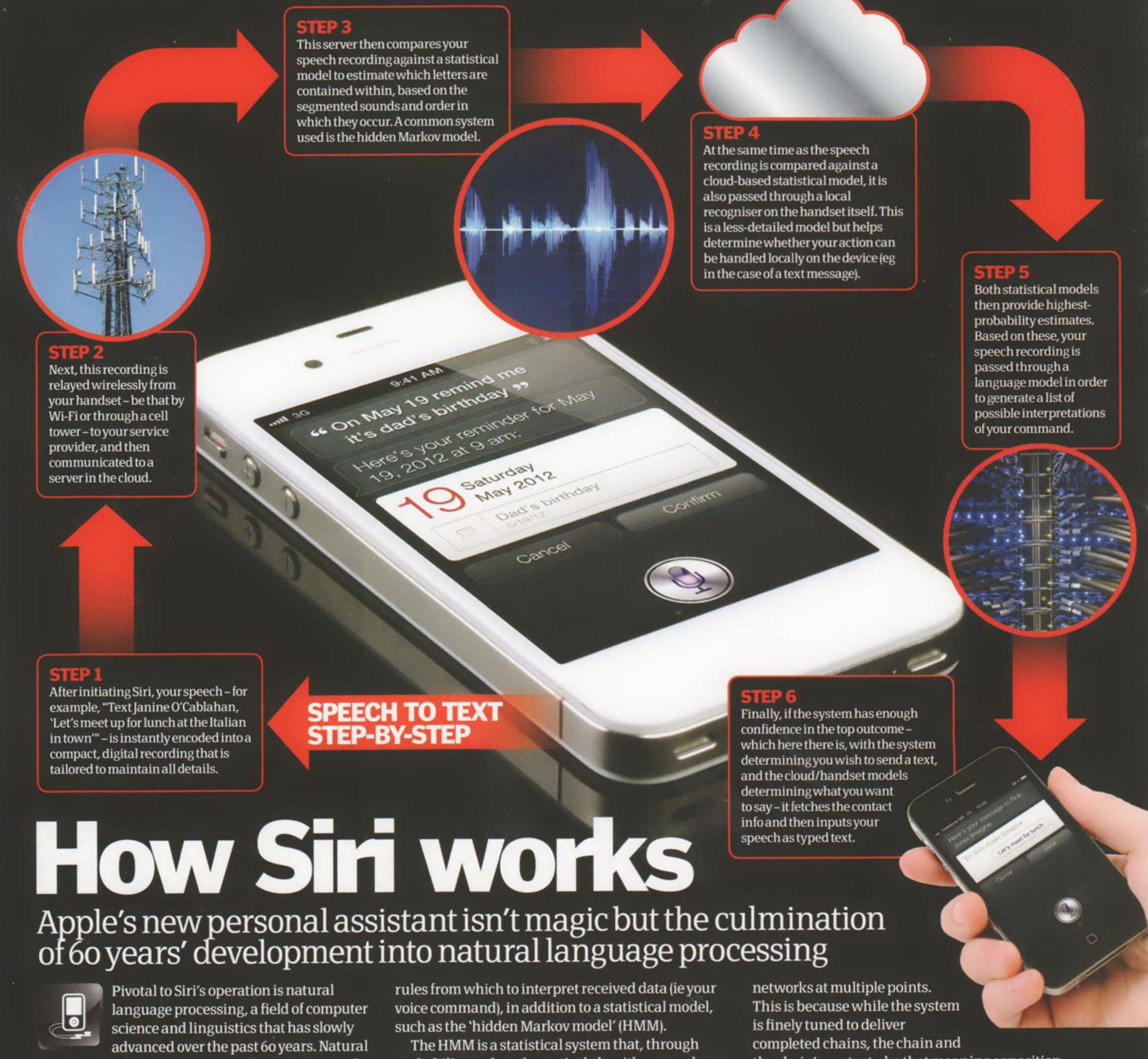
“Siri uses probability and mathematical algorithms to analyse the smallest units of spoken sound”

Apple's voice-recognition tech


9:41 AM
3G
“On May 19 remind me it's dad's birthday”
Here's your reminder for May 19, 2012 at 9 am:
19
Saturday
May 2012
Dad's birthday
5/19/12
Cancel
Confirm

SPEECH TO TEXT STEP-BY-STEP

STEP 1
After initiating Siri, your speech – for example, "Text Janine O'Cablahan, 'Let's meet up for lunch at the Italian in town'" – is instantly encoded into a compact, digital recording that is tailored to maintain all details.

STEP 2
Next, this recording is relayed wirelessly from your handset – be that by Wi-Fi or through a cell tower – to your service provider, and then communicated to a server in the cloud.

STEP 3
This server then compares your speech recording against a statistical model to estimate which letters are contained within, based on the segmented sounds and order in which they occur. A common system used is the hidden Markov model.

STEP 4
At the same time as the speech recording is compared against a cloud-based statistical model, it is also passed through a local recogniser on the handset itself. This is a less-detailed model but helps determine whether your action can be handled locally on the device (eg in the case of a text message).

STEP 5
Both statistical models then provide highest-probability estimates. Based on these, your speech recording is passed through a language model in order to generate a list of possible interpretations of your command.

STEP 6
Finally, if the system has enough confidence in the top outcome – which here there is, with the system determining you wish to send a text, and the cloud/handset models determining what you want to say – it fetches the contact info and then inputs your speech as typed text.

How Siri works

Apple's new personal assistant isn't magic but the culmination of 60 years' development into natural language processing

Pivotal to Siri's operation is natural language processing, a field of computer science and linguistics that has slowly advanced over the past 60 years. Natural language processing, which itself contains myriad sub-processes such as speech segmentation, is the overarching system that allows Siri to accurately – in most cases – respond to your commands. Key to the whole function, however, are statistical models.

Statistical natural language processing, as used by Siri, employs chance and probability to resolve the required range of sub-processes. These processes often use corpora (a large volume of known, real-world data) to derive a set of abstract rules from which to interpret received data (ie your voice command), in addition to a statistical model, such as the 'hidden Markov model' (HMM).

The HMM is a statistical system that, through probability and mathematical algorithms, analyses a spoken command's sequence of phonemes (the smallest unit of spoken sound) to generate a chain – the completed chain forming a single word. It does this by assigning a probability score to each phoneme, before determining which word the individual phonemes amount to.

The statistical models, however, rely on the system's training data – eg the corpora – referencing acoustic models, word lists and probability networks at multiple points. This is because while the system is finely tuned to deliver completed chains, the chain and the chain's context – be that meaning or position within an extended command – varies depending on non-statistical variables.

Due to the vast complexity and processing power necessary to analyse any spoken command, the majority of Siri's natural language processing is handled in the cloud, with a handset consulting remote servers to quickly supply a response. This process is explored in detail in the 'Speech to text step-by-step' diagram above. ✤

5 TOP FACTS TATTOO GUNS

Stencil

1 The first tattoo gun was an evolution of Thomas Alva Edison's Stencil-Pen, which was patented in Newark, USA, in 1876. The pen was originally conceived to replicate images.

Face

2 Due to rapid improvements in the precision of tattoo guns, a new form of facial tattooing has emerged in the last decade called dermapigmentation, a kind of permanent cosmetics.

Misnomer

3 Interestingly, many professional tattoo artists look down on the term 'tattoo gun'. Most who work in the industry prefer to use the terms 'tattoo machine' or 'tattoo iron'.

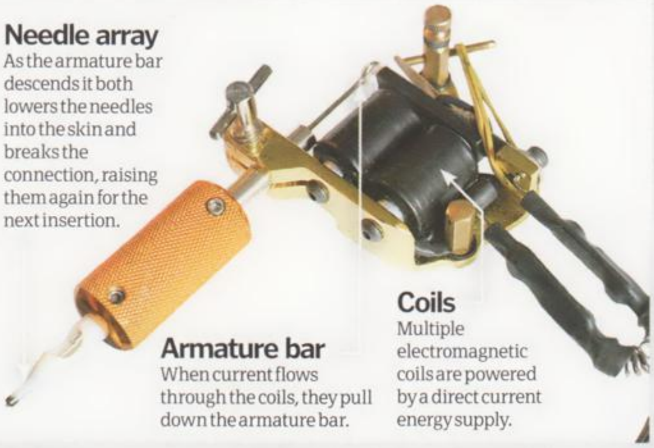
Control

4 Modern tattoo guns offer super-refined control over their operation, allowing the artist to select the depth, force and speed of the needles' application to the skin.

London

5 The first proper tattoo gun was patented in London by engineer Samuel O'Reilly in 1891. The first coil-based tattoo gun was also patented in London.

DID YOU KNOW? The Tugaslugabed alarm clock, circa 1910, awoke sleepers by pulling a loop of string attached to one toe



Needle array
As the armature bar descends it both lowers the needles into the skin and breaks the connection, raising them again for the next insertion.

Armature bar
When current flows through the coils, they pull down the armature bar.

Coils
Multiple electromagnetic coils are powered by a direct current energy supply.

How do tattoo guns work?

The invention designed to transform the skin into a living canvas

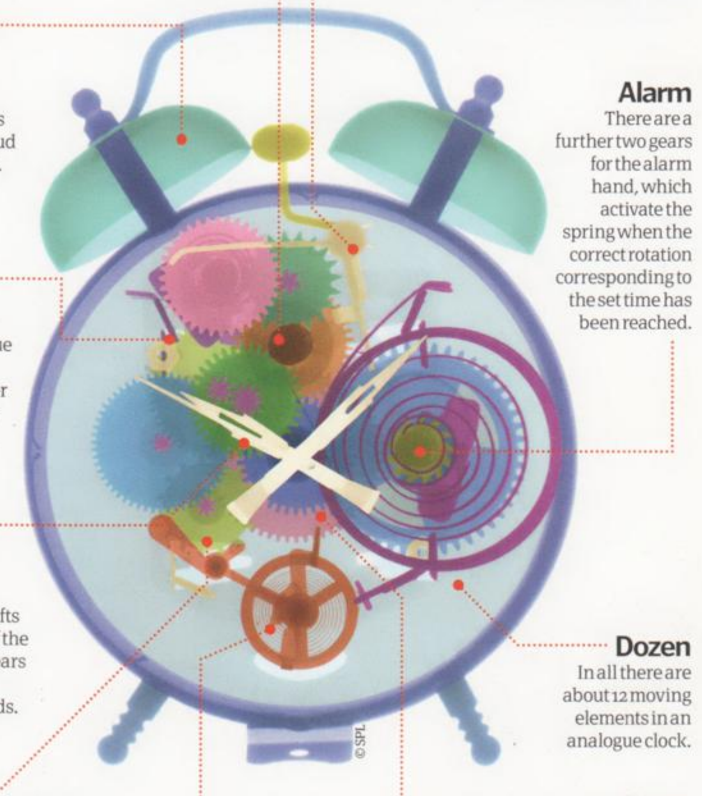
Tattoo guns, also commonly known as tattoo irons or machines, come in a variety of forms. The most common variant, however, is the coil type, which utilises a series of electromagnetic coils to raise and lower needles into the skin to deposit the ink. These devices work by connecting an armature bar via a spring to a base unit, which itself contains between one and three electromagnetic coils. The coils connect to a DC power supply via a sprung U-cable and, when powered, act as an electromagnet, pulling down the armature bar.

Attached to the armature bar is the machine's needle array, and as it descends so too do the needles, piercing the skin and depositing ink just below the surface. At the bottom of the bar's descent its connection with the electromagnet breaks and, as a result, it lifts back to the default position. As such, the needles are constantly drawn up and down at a high speed in a cycle.

An international tattoo convention is held each year in London

Inside an analogue alarm clock

What makes these mechanical time machines tick?



© SPL

Synchronised
With every second that passes, a chain of wheels synchronises the gears and operators to ensure they accurately track the motion of time.

Ring
An extra hand is used for the alarm. A spring is pressed against the mechanism of the bell hammer and, when the alarm time comes around, tension in the spring is released, causing the hammer to strike the bell(s).

Bell
The majority of analogue alarm clocks use metal bells to provide a loud ringing sound.

Alarm
There are a further two gears for the alarm hand, which activate the spring when the correct rotation corresponding to the set time has been reached.

Power
The various mechanisms inside analogue clocks are powered either by batteries or DC electricity.

Hands
The hands of the clock are connected to concentric shafts at the centre of the clock where gears turn them at different speeds.

Dozen
In all there are about 12 moving elements in an analogue clock.

Time
The gears inside control the hands of the clock. An oscillating wheel ensures the gears move consistently at the same speed.

Main wheel
Analogue clocks, like wrist watches, use an oscillating wheel to turn the clock's hands.

Gears
Four gears between the spring and the main wheel are responsible for turning the hands of the clock.

Personal CNC for Home or Hobby

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Shown here with optional stand, LCD monitor, machine arms, and accessories.

"The chippings of wood are then fed into large pressure boilers called digesters"

A large machine reel of finished paper

Inside paper making

The technology and techniques used to create this piece of paper explained

The base ingredient of the majority of papers is wood, so the first step in paper manufacturing is the harvesting of trees. Once the trees have been felled and shred down to their trunks, they are transported to a paper mill. Once they arrive the trunks are fed through a bark-skimming drum in which they are forced to collide and rub together. This process removes the trunks of all their bark, which while useful in other applications – such as being burned as boiler fuel – is detrimental to creating clean white paper.

In the next stage of the process, the de-barked logs are sent to a massive chipping unit, which breaks them down into small pieces. The chippings of wood are then fed into large pressure boilers called digesters. These reduce the wood chippings to a gloopy oatmeal-like pulp, which when extracted from the digester rests at a composition of one part fibre to 200 parts water.

The pulp is then deposited onto a high-speed, mesh screen loop, which removes most of the water content and leaves a thin layer of raw paper. This raw paper is pressed and heated in a series of drying cylinders where any remaining traces of moisture are removed. Finally the paper is treated with a starch solution that seals the surface and helps avoid excessive ink absorption during printing.

Historically paper production has transitioned through three main phases, ranging from the manual and bespoke creation of single small sheets from plant and rag fibres, through larger-scale, water-powered paper mills and on to current fully automated and continuous papermaking facilities.

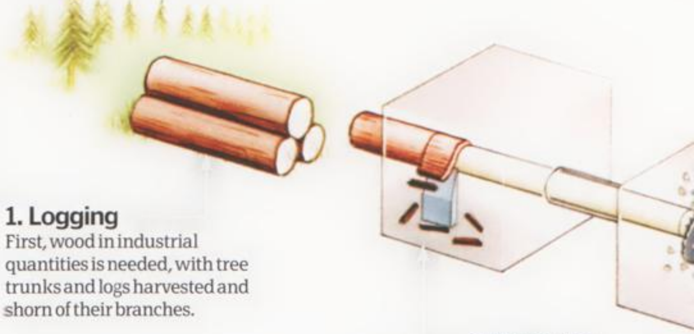
Today, many new hardback titles are produced from wood-free paper, which is created exclusively from chemical pulp (a process where the lignin is totally separated from the cellulose fibres during processing) as it is not as prone to yellowing as traditional, wood-based pulp paper.

Wood chippings are the base of the vast majority of paper produced today

© Terry Robinson

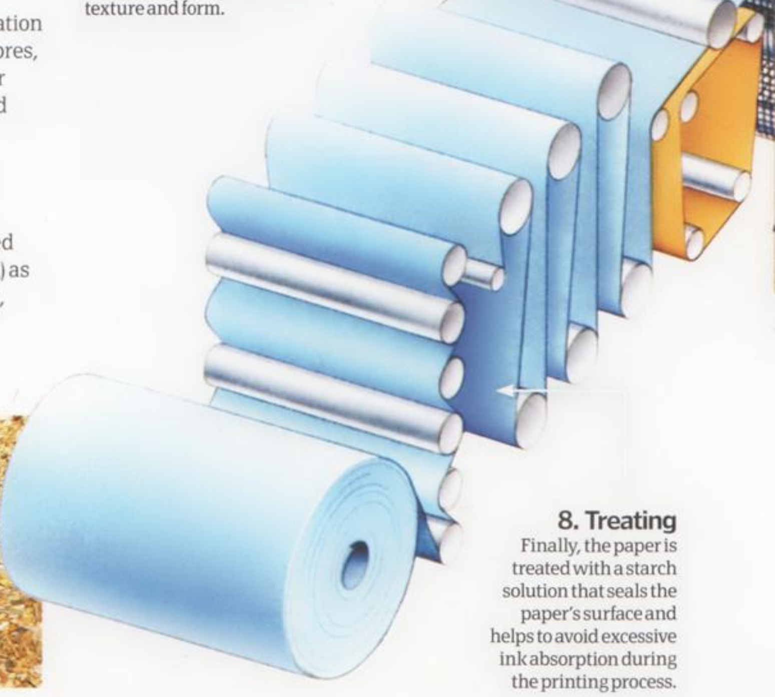
The paper mill production line

From wooden logs to a finished pack of white A4, follow paper manufacturing step by step



1. Logging
First, wood in industrial quantities is needed, with tree trunks and logs harvested and shorn of their branches.

2. Stripping
The trunks/logs are then sent through a stripping machine, which quickly and efficiently removes their bark.



6. Drying
The remaining raw fibrous paper layer is then passed through numerous drying cylinders in order to solidify its structure.

7. Pressing
Penultimately, the paper is fed through a pressing unit, which equalises its surface texture and form.

8. Treating
Finally, the paper is treated with a starch solution that seals the paper's surface and helps to avoid excessive ink absorption during the printing process.

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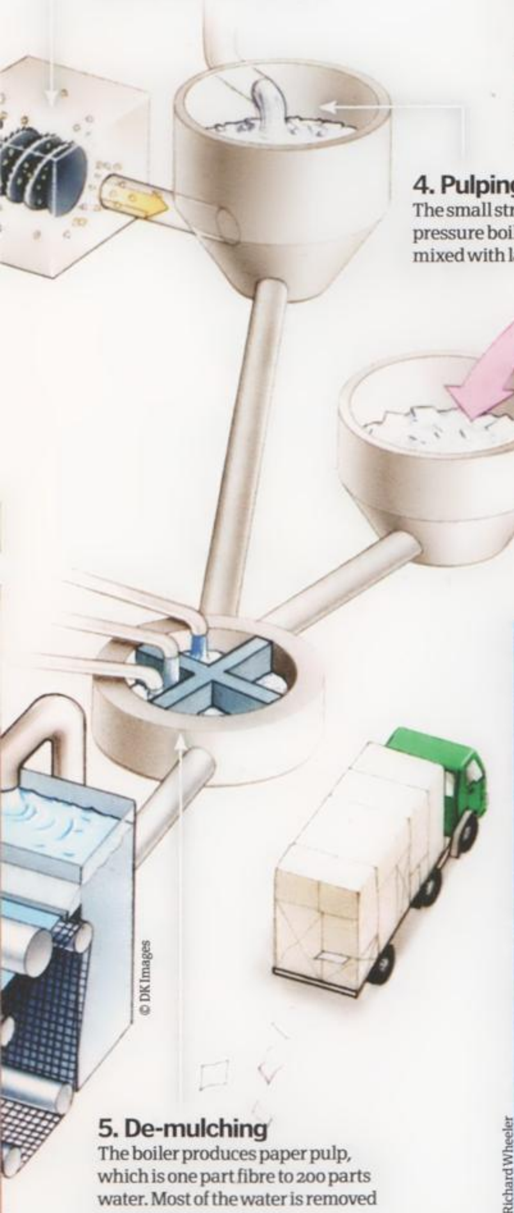
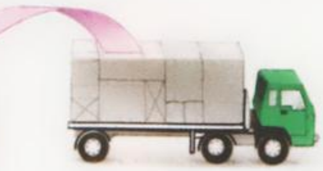
DID YOU KNOW? The first papermaking machine was patented in France in 1799





3. Chipping
The de-barked wood is then thrown into a chipping unit, which shreds them down into small strips.

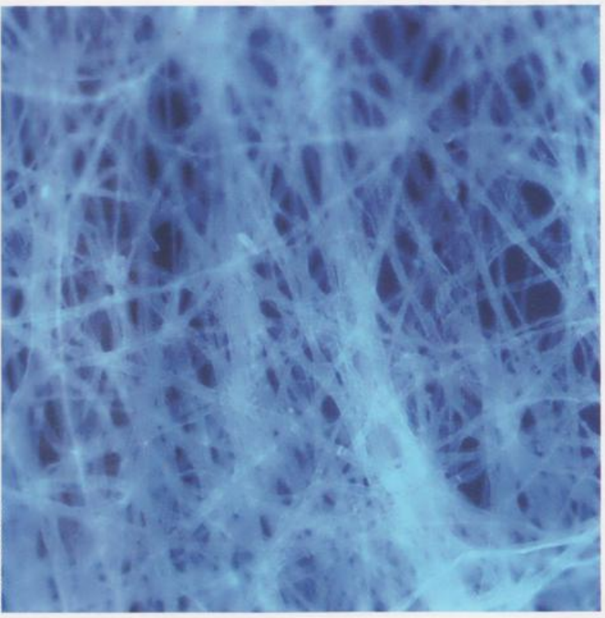
4. Pulping
The small strips are deposited into a large pressure boiler (digester), where they are mixed with large quantities of water.

5. De-mulching
The boiler produces paper pulp, which is one part fibre to 200 parts water. Most of the water is removed via a mesh screen loop.

© DK Images

> "Today, many new hardback titles are produced from wood-free paper created exclusively from chemical pulp"

A fantastic closeup of a sheet of paper's fibres. The fibres appear blue due to autofluorescing under ultraviolet illumination



© Richard Wheeler

Take a peak inside a 19th-century paper mill

One of the huge rollers which ensures the paper's thickness is uniform

2,000 years of paper

Follow our chronological guide and learn about the evolution and uses of this most versatile manmade material

105 AD

An official attached to China's ruling Han Dynasty creates a single sheet of bespoke paper using mulberry, bast fibres, fishnets and hemp waste.

300 AD

Crude fibrous paper starts to be widely used as a writing medium, with religious officials utilising it for both academic and holy texts.

589 AD

The Chinese begin to use paper as toilet roll.

618 AD

Paper begins to be utilised for other purposes, such as a protective material for wrapping perishable produce, gifts and poisonous substances.

750 AD

Papermaking leaves the Far East and the first water-powered mills are created to produce paper in Samarkand, Persia, along with pump mills.

1220 AD

The papermaking craft diffuses out of the Middle East and into the West, with records showing Italian and later German paper mills appearing. The Gutenberg Bible is created in the 1450s.

1801 AD

Henry Fourdrinier and John Gamble create the Fourdrinier machine, the first continuous papermaking machine in the world.

1844 AD

The first wood-pulping machine is invented, enabling paper to be made from wood pulp rather than the more costly rag variety.

1900 AD

The mass-production of paper causes an explosion in produced written texts, leading to the rise and rise of the modern daily newspaper.

2010 AD

Apple releases its iPad tablet computer, initiating a transition from the physical, paper-based document to a digital replica.

> "Once melted, the chocolate is drawn into a hollow cylinder that extends upwards from the bowl"

Fun, tasty and all thanks to Ancient Greek physics!

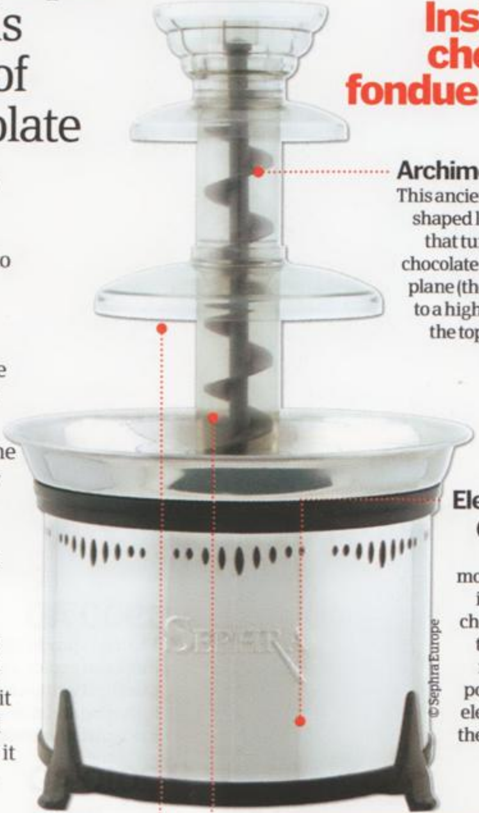
How do chocolate fountains flow?

An ancient principle is the key to this decadent way of enjoying chocolate

Chocolate fountains use a mechanism known as the Archimedes' screw to transfer liquid chocolate to a higher plane. To melt the chocolate a heating element is positioned within the base of the device, below a metal bowl that acts like a reservoir for the liquid chocolate. Once melted, the chocolate is drawn into a hollow cylinder that extends upwards from the bowl.

Inside the cylinder is a helical threaded screw mechanism powered by a small motor. The motor turns the screw, enabling liquid to be transferred from the bottom up along the screw until it reaches the top. When the liquid arrives at the summit of the pipe it empties out over a series of tiers – usually two or three – before cascading as a uniform chocolate curtain back down into the bowl below where the whole process can begin again.

Inside the chocolate fondue device


© Sephra Europe

Archimedes' screw
This ancient mechanism is shaped like a large screw that turns, transferring chocolate from a low-lying plane (the bowl) upwards to a higher-lying plane at the top of the machine.

Electric motor (not shown)
A small electric motor is positioned in the base of the chocolate fountain to turn the screw mechanism and power the heating element that melts the solid chocolate.

Tiers
A number of smooth tiers allow the chocolate to flow out and down into the main bowl below.

Cylinder
The pipe surrounding the screw prevents the chocolate from spilling straight back down into the base.

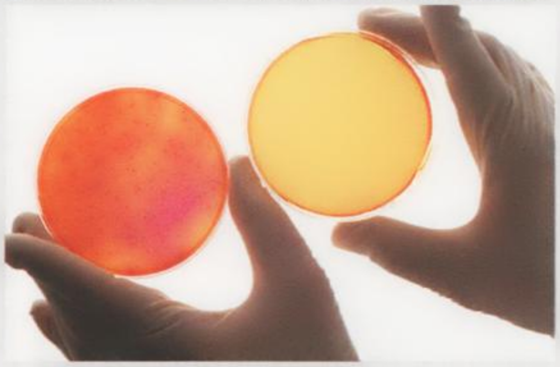
Ionising air purifiers

How do these popular air-cleansing devices ensure a room is kept ultra-fresh?

Ionising purifiers expel ions at a high velocity into their surrounding environment. They achieve this by forcing electrons into a metal needle en masse within the ioniser's casing, causing them to build up at the tip and then be expelled into the surrounding air, attaching themselves to air molecules and becoming ions. This effect produces a cloud of ions in the immediate vicinity of an ioniser, which over time spread outwards through a room.

As these ions collide with other airborne particles – such as smoke, dust or bacteria – they pass on their static charge (usually negative) and force them to become strongly attracted to the closest earthed surface, such as the ioniser's own filter, a wall or carpet. As more and more fine particles are attracted to the ion, they grow in size to the point where they become too heavy to be carried in the air and fall to the nearest surface, allowing them to be collected by a vacuum cleaner or similar device.

An image showing the sterilising effects of an ionising purifier. The petri dish on the left is contaminated with salmonella enteritidis, but when it is deposited in an ioniser, it is purified, as shown on the right



Always on your smartphone, or still asking a policeman? Discover how emerging technologies will change the way we access and experience London and compare with past visions of the future

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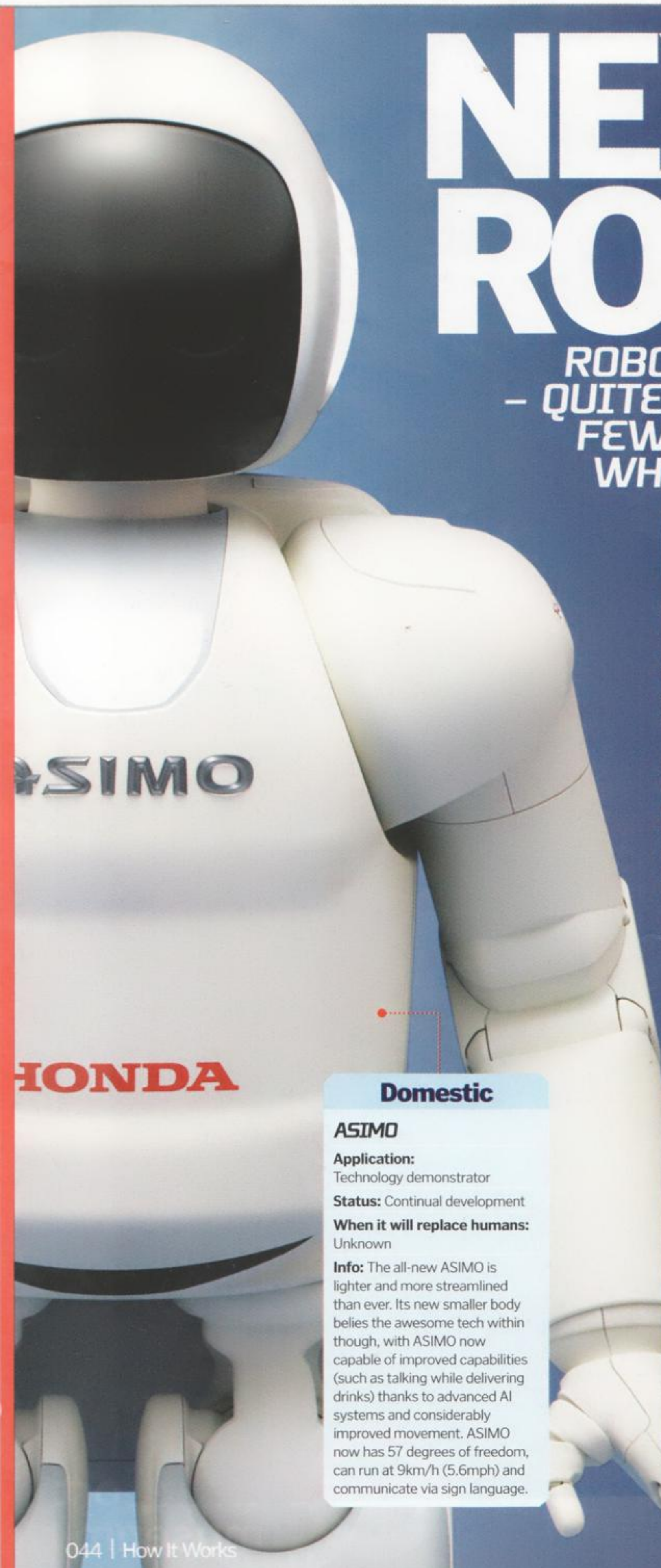
SENSE AND THE CITY

Smart, connected and on the move

MAYOR OF LONDON

london transport museum

> "Integration with other technologies is making a huge difference to development"



NEXT-GEN ROBOTICS

ROBOTS ARE MAKING GREAT STRIDES – QUITE LITERALLY – SO THE UPCOMING FEW YEARS PROMISE TO USHER IN A WHOLE NEW ERA FOR AUTOMATONS

Without a doubt, robots have captured the imagination of science-fiction writers and filmmakers over the last 80 years, but even the best efforts of engineers have so far fallen short of the vision of the graceful, intelligent, self-aware machines that aim to kill us, love us or become more human.

The application of advanced systems and technology throughout the modern world begs a re-evaluation of the question: what is a robot? Going back to the basic definition of the word, which comes from the Czech *robota*, meaning forced labour, a robot could be anything that performs a physical task for a user.

Available technology has generally limited robot development relative to the imagination of writers and filmmakers. Computer processing capability is currently at a level that allows very sophisticated software to be used, with a large number of advanced sensors and inputs giving huge amounts of information for the software to utilise. One example is the Samsung Navibot, which negotiates its environment with a host of sensors and clever programming to map a room, store the room shape in its memory, define its position and vacuum-clean the floor before returning to a special dock to recharge itself.

Decades of research and development in key areas have begun to pay off, with significant weight reductions and increased structural strength made possible by advancements in carbon fibre and composite material technology. Mechanical and ergonomic research has been instrumental in domestic and care applications, such as the Japanese robot RI-MAN, which easily lifts patients in care homes to save both staff and patients risking injury. Robot/human interaction research is also allowing machines to be tailored to be more widely accepted and trusted, especially with vulnerable or disabled users. NAO is a good

Domestic

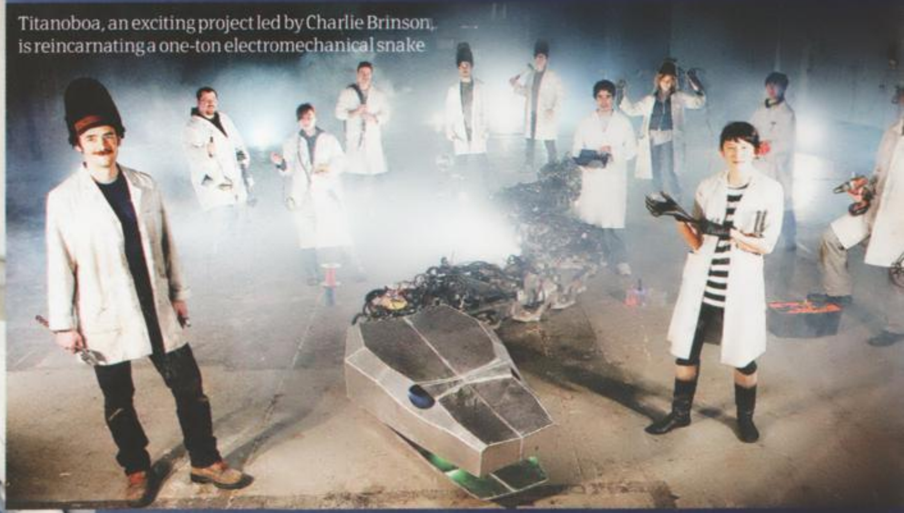
ASIMO

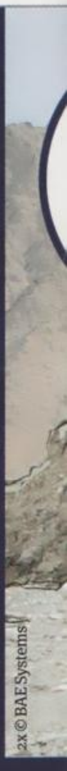
Application: Technology demonstrator

Status: Continual development

When it will replace humans: Unknown

Info: The all-new ASIMO is lighter and more streamlined than ever. Its new smaller body belies the awesome tech within though, with ASIMO now capable of improved capabilities (such as talking while delivering drinks) thanks to advanced AI systems and considerably improved movement. ASIMO now has 57 degrees of freedom, can run at 9km/h (5.6mph) and communicate via sign language.


Titanoboa, an exciting project led by Charlie Brinson, is reincarnating a one-ton electromechanical snake


2x © BAE Systems

5 TOP FACTS CUTTING-EDGE BOTS

ASIMO

1 Developed over 20 years by Honda, ASIMO pushes robot tech in every area, being a pioneer of walking, running, robot/human interaction and environmental awareness.

Robonaut 2

2 Developed for the International Space Station (ISS), the Robonaut is a waist-up humanoid torso. With arms and fingers, it is able to use tools designed for humans.

Taranis

3 Far superior to a manned aircraft and able to make its own decisions about taking human life, BAE's Taranis really takes us into the terrifying realms of science fiction.

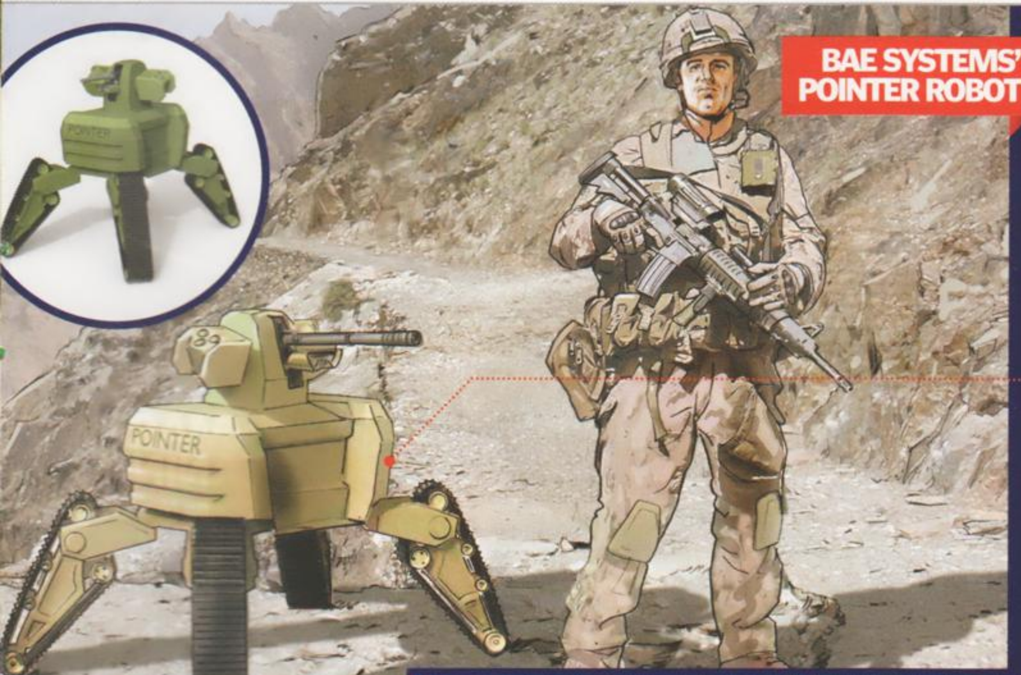
Curiosity Mars rover

4 Intelligent, semi-autonomous and jam-packed with scientific apparatus, including a laser and nuclear battery, this car-sized robot has all it needs to study the Red Planet.

da Vinci medical robot

5 Able to assist or conduct operations remotely under the control of a surgeon, the multiple arms of this machine point towards an exciting relationship between robots and doctors.

DID YOU KNOW? ASIMO was able to move in such a humanlike manner, Honda sought blessing from the Vatican to develop it



Military

BAE Pointer

Application: Soldier

Status: In development

When it will replace humans: 2020

Info: BAE's Pointer is a concept vehicle recently presented to the UK government as part of its Future Protected Vehicles programme. The Pointer is a robotic soldier designed to carry out repetitive or dangerous reconnaissance work in the field, eg sweeping for mines. It can travel at high speed on its horizontal tracks or walk like a spider. Its body was designed to be modular, allowing for a variety of configurations, be that a support of human troops with an autocannon, acting as a medibay or delivering battlefield intel as a highly mobile mechanised scout.

ROBOT LAWS

Science-fiction writer Isaac Asimov introduced the three laws of robotics in a 1941 story. These are:

1 A ROBOT MAY NOT INJURE A HUMAN BEING, NOR THROUGH ITS INACTION ALLOW A HUMAN BEING TO COME TO HARM

2 A ROBOT MUST OBEY THE ORDERS GIVEN TO IT BY HUMAN BEINGS, UNLESS SUCH ORDERS WOULD VIOLATE THE FIRST LAW

3 A ROBOT MUST PROTECT ITS OWN EXISTENCE, AS LONG AS THIS DOES NOT CONFLICT WITH THE FIRST TWO LAWS.

BAE SYSTEMS' TARANIS ROBOT

Although the Taranis will ultimately be controlled by a team on the ground, it will still be able to make its own judgement calls within a preprogrammed remit

2x © BAE Systems

Military

BAE Taranis

Application: Unmanned combat air vehicle (UCAV)

Status: In development

When it will replace humans: 2018

Info: BAE's Taranis is named after the Celtic god of thunder and has been designed to explore how an autonomous vehicle – controlled by a team of skilled, ground-based operators – can perform many of the roles undertaken by human pilots while remaining non-detectable to radar. Due for flight trials this year, the Taranis relays info back to command at which point it can engage a target if it sees fit.

© Michael J P Hall

example of this as its cartoon-like features make it look friendly, which is ideal in its role of supporting the teaching of autistic children.

Integration with other technologies is another key capability that is making a huge difference to development, with existing global positioning systems and communication networks allowing autonomy at never-before-seen levels of accuracy, cost and reliability.

The internet has proven invaluable in offering access to similar lines of research, the sharing of open-source materials and the easy exchange of opinion and resources, which benefits the improvement of technologies. One interesting use of the web is to easily and reliably control robotic systems from anywhere in the world, allowing machines like the da Vinci medical robot to be used by the best surgeons on the planet, while in a different country to the patient if necessary.

Military applications have traditionally pushed the development of technology, and robotics is an area that is benefiting from this, with many unmanned and autonomous aircraft, tracked and wheeled vehicles, snakes and microbots being designed to suit the modern battlefield. Assets such as BAE's Taranis robotic stealth fighter promise high capability, high autonomy and come at a high price, but the development of low-cost, flexible solutions for information gathering, bomb disposal and troop support is evident with the stealthy snake-like robots making excellent progress with several armies, and systems like BAE's Pointer and Boston Dynamics' LS3 taking over many repetitive, dull and risky jobs.

We see the benefits of these next-gen robots every day. Autonomous satellites provide GPS navigation for our cars, as well as data links for our mobile phones and computers. Cutting-edge robot technology is making the mass production of items from drinks cans to cars evermore efficient and cost effective, thanks to the progression of industrial robotic systems. Unmanned warehouse and production-line robots move goods around factories, while the level of autonomous control that modern cars have over their brakes, power and stability systems to improve safety takes them very close to the definition of a robot. The mass-market autonomous car is likely only a few years away, with most major manufacturers such as Volvo and BMW having developed driverless technology demonstrators, but it is the human element in this holding the systems back more than the technology, as many people feel very uncomfortable putting their lives in the 'hands' of a robot driver.

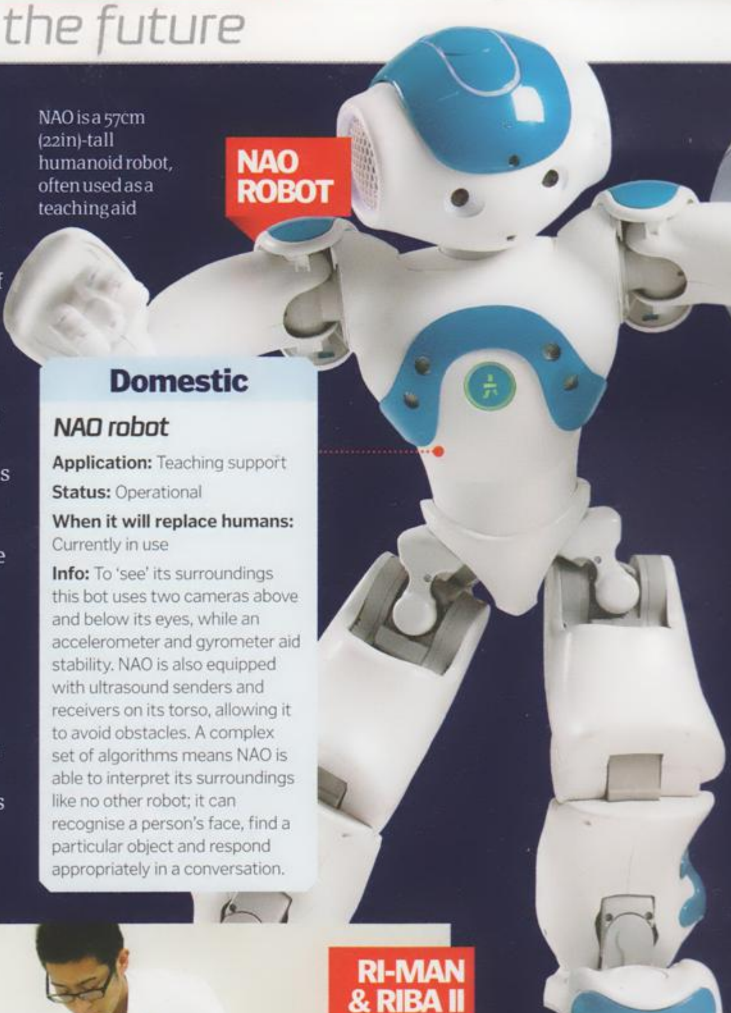
Scientific and space research is an area to which next-gen bots are well suited, with machines such as the ▶

"The quantum computer may be with us in just a few years"

NASA Dawn spacecraft excelling in their roles. Using an advanced ion engine to move around the solar system, this small, low-budget craft is performing a mission which would be impossible with manned systems. Similar robots can keep humans out of danger in arctic, deep-sea or volcanic research as conducted by the eight-legged Dante II in 1994.

We are on the verge of further technological breakthroughs that will transform the capabilities of robots. The quantum computer may be with us in just a few years, and could give a huge increase in processing power while power-generation tech has made a huge leap recently with lithium-based systems. Traditional motors for controlling robots may be replaced with new tech based on expanding/contracting memory metals, electro-reactive materials or other means proving to be more efficient or precise. The next generation of robots is now arriving; who knows what's waiting around the corner? ✿

NAO ROBOT



NAO is a 57cm (22in)-tall humanoid robot, often used as a teaching aid

© Aldebaran Robotics

Domestic

NAO robot

Application: Teaching support

Status: Operational

When it will replace humans: Currently in use

Info: To 'see' its surroundings this bot uses two cameras above and below its eyes, while an accelerometer and gyrometer aid stability. NAO is also equipped with ultrasound senders and receivers on its torso, allowing it to avoid obstacles. A complex set of algorithms means NAO is able to interpret its surroundings like no other robot; it can recognise a person's face, find a particular object and respond appropriately in a conversation.

Domestic

Samsung Navibot

Application: Cleaning

Status: Developed product

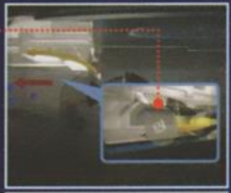
When it will replace humans: On sale now

SMART CLEANING

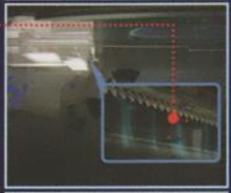
The Samsung Navibot has 38 sensors to map rooms, avoid bumps and recharge itself

1. Looking up The top houses the infrared roof sensor that shows Navibot the shape of the room.

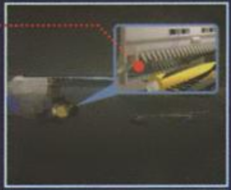
2. Brush Following an efficient pattern within the room, the power brush sweeps the whole floor.



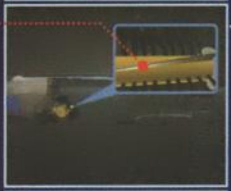
3. Suck-up Dust is sucked up into the bin by the powerful vacuum, from both carpet and smooth floors.



4. Teeth The brush pulls through teeth inside the body, next to infrared sensors which detect drops.



5. Hair-free The anti-tangle system ensures that no long strands of hair jam up the rotating brush.



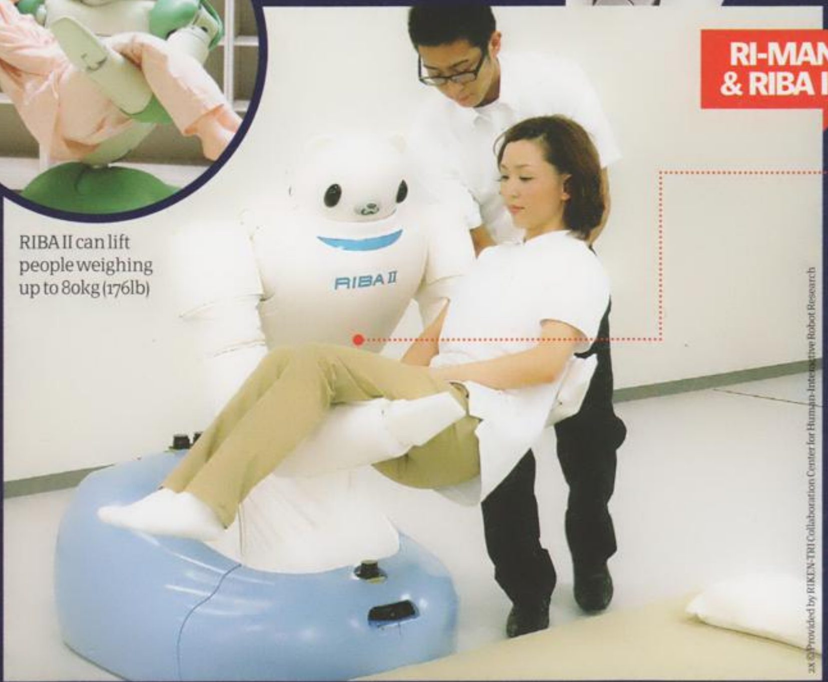
6. Allergy The hyper-allergenic filter can be cleaned and the vacuum can be set to operate daily.

© Samsung

2x © Harvard University

RIBA II can lift people weighing up to 80kg (176lb)

RI-MAN & RIBA II



2x © Provided by RIKEN-TRI Collaboration Center for Human-Interactive Robot Research

Domestic

RI-MAN and RIBA II

Application: Care work assistance

Status: Operational

When it will replace humans: Currently in use

Info: RIBA (Robot for Interactive Body Assistance) evolved RI-MAN's ability to lift and set down a human; RIBA II can lift up to 80kg (176lb). Joints in the base and lower back allow the bot to crouch down to floor level, while rubber tactile sensors enable it to safely lift a person. These sensors let the robot ascertain a person's weight just by touching them, so it knows how much force to apply when picking them up.

ROBOTIC LANDMARKS

1938
Auto paint sprayer
Harold Roselund and William Pollard pioneer industrial production robotics with an automated paint-spraying arm.

1939
Elektro
While stories depicted intelligent, humanlike robots, this mechanical man appeared at the 1939 World's Fair.

1948
Robot tortoise
With autonomous roaming, obstacle avoidance and light sensitivity, this bot was well ahead of its time.

1950
Isaac Asimov
I, Robot, the book that defined our modern take on robots, was based on Asimov's three laws of robotics.

1954
Programming
The first programmable robot was designed by George Devol, who started Unimation, the first robotics company.

© NASA

Head to Head
MEAN MACHINES

1. Wheely Big Cheese
A favourite from the TV show *Robot Wars*, Wheely Big Cheese is made of titanium and is powerful enough to flip a car.

© QinetiQ North America

2. TALON IV
This tracked robot, which is currently used in many search-and-rescue roles, can also carry machine guns and cannons if firepower is required.

3. Taranis
BAE's large robotic fighter-plane can carry a range of weapons, employ stealth technology and fight multiple enemies without any human involvement.

DID YOU KNOW? Future planet exploration may be done with robot snakes and spiders, as wheels can struggle in this terrain

Lifesaving
'Soft Robot' Starfish

Application: Search and exploration

Status: In development

When it will replace humans: 2025

Info: Scientists at Harvard University are engineering flexible, soft-bodied (elastomeric polymer) robots inspired by creatures like squid and starfish. Capable of complex movements with very little mechanisation, this sort of bot could be used in search-and-rescue operations following earthquakes. The multi-gait robot is tethered to a bottle of pressurised air, which pulses through the hollow-bodied robot to generate simple motion.

Lifesaving
Emergency Integrated Lifesaving Lanyard (EMILY)

Application: Lifeguard

Status: Operational

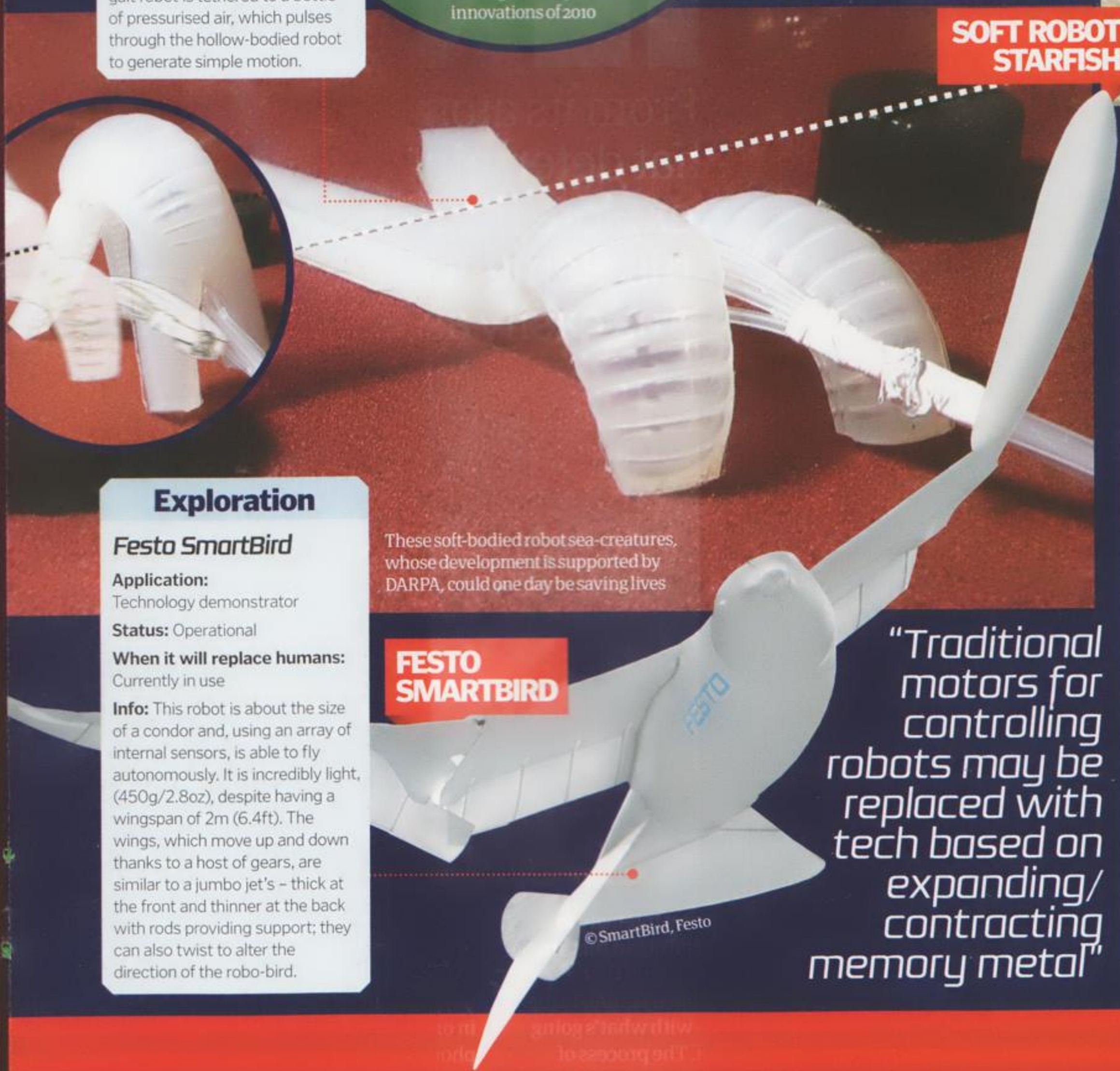
When it will replace humans: Currently in use

Info: EMILY is a 1.5m (5ft)-long remotely controlled buoy used to rescue swimmers in distress. The buoy can race across the ocean at 39km/h (24mph), enabling swift rescues. It has been advanced with sonar-detection tech which helps it to find and identify distressed swimmers on its own. Once EMILY has reached the swimmer, they can either hang on to the buoy and await a lifeguard, or the buoy can tow them ashore itself.

LIFESAVING LANYARD

EMILY featured in the top ten of *TIME Magazine*'s 50 best innovations of 2010

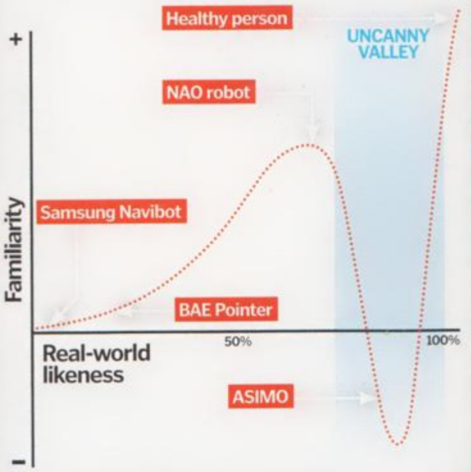
2x © Hydronalix



These soft-bodied robot sea-creatures, whose development is supported by DARPA, could one day be saving lives

© SmartBird, Festo

UNCANNY VALLEY
Humans have evolved to be repelled by certain things. Aversions to smells, tastes and the way things look are ways of protecting ourselves, eg a dead body produces a strong feeling of discomfort, even if it's much the same as a living one. The 'uncanny valley' theory states we show greater affection towards objects as they become more humanlike, but there comes a point where they get too close, in manner or appearance, triggering repulsion. The key is for robots to be endearing but not too realistic.



Exploration
Festo SmartBird

Application: Technology demonstrator

Status: Operational

When it will replace humans: Currently in use

Info: This robot is about the size of a condor and, using an array of internal sensors, is able to fly autonomously. It is incredibly light, (450g/2.8oz), despite having a wingspan of 2m (6.4ft). The wings, which move up and down thanks to a host of gears, are similar to a jumbo jet's – thick at the front and thinner at the back with rods providing support; they can also twist to alter the direction of the robo-bird.

> "Traditional motors for controlling robots may be replaced with tech based on expanding/contracting memory metal"

1957
Sputnik I
The very first space robot, though primitive by modern standards, kicked off the Space Race.

1970
Computer control
The Stanford Research Institute develops the first robots that are controlled by computers; these were called Cart and Shakey.

1986
Honda EO
Honda begins building walking humanoid robots, investing 25 years and huge resources into development; this leads on to ASIMO.

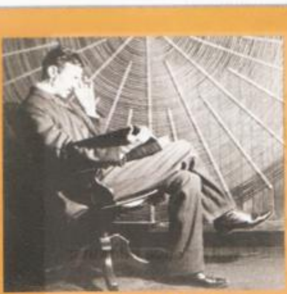
1997
RoboCup
The first tournament that aims to have a robot football team one day beating humans is held.

2011
Robonaut 2
NASA launches the second robot astronaut, which can operate tools and assist human astronauts in orbit.

© NASA

2020?
Next-gen robots
The next few years should see robots with quantum computer brains and biomechanical muscles become a reality.

Inside infernos



This month in **Science**

Things are getting seriously hot in Science this month as we look at one of the most powerful forces of nature – fire. Elsewhere we explore the body, discovering how metabolism is vital to our survival, how adenoids ward off oral infection and the mysterious sleeping disorder narcolepsy. The work of Nikola Tesla is also celebrated – plasma globes for one thing!

55 Metabolism

58 Plasma globes

59 Motion sickness

SCIENCE

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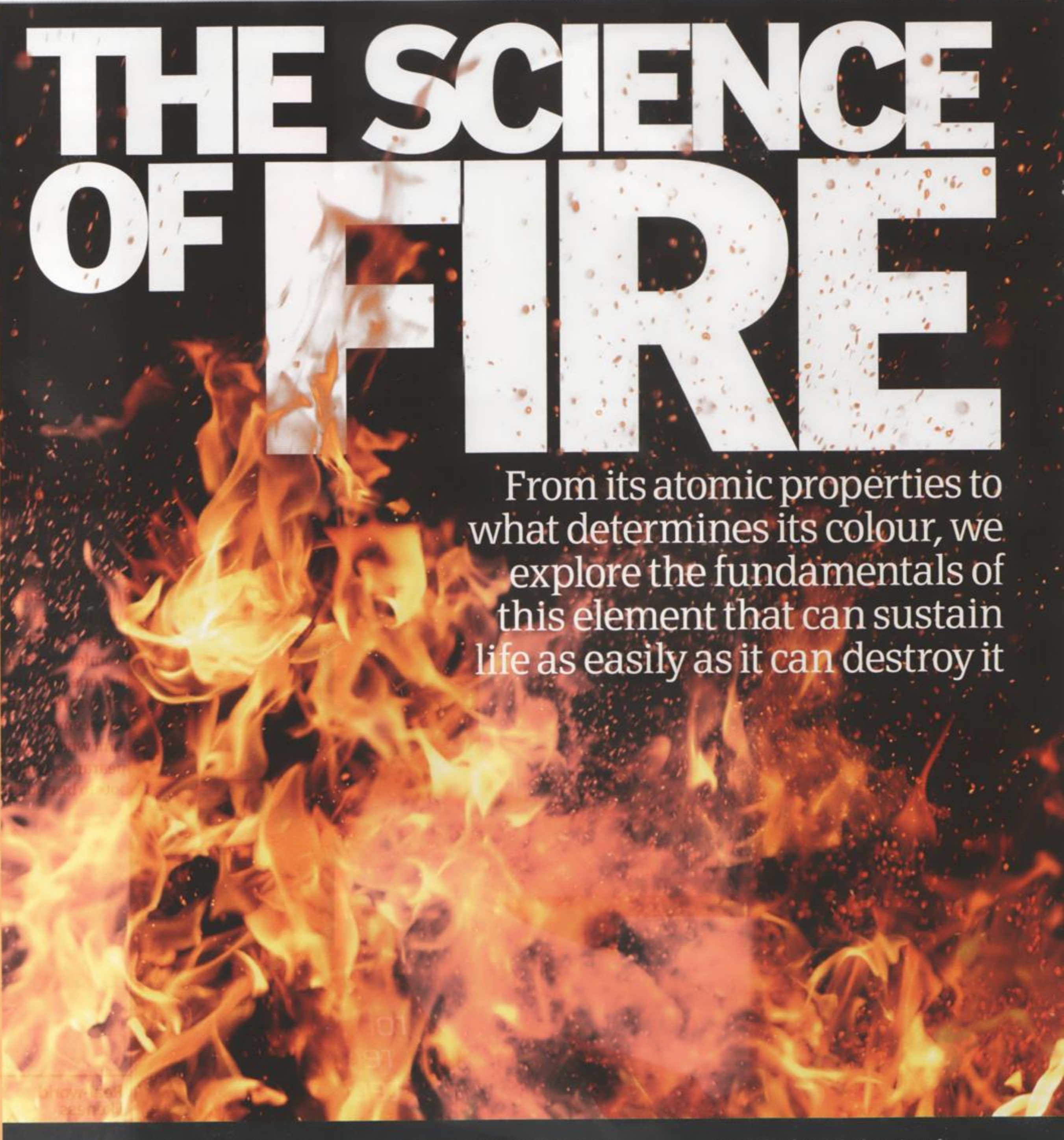
THE SCIENCE OF FIRE



From its atomic properties to what determines its colour, we explore the fundamentals of this element that can sustain life as easily as it can destroy it

Most of us encounter some form of fire every day, whether we're basking in the rays of the Sun, lighting a match or cooking food. It's likely that early man 500,000 years ago didn't quite have the method of creating fire nailed down, instead relying on natural occurrences such as lightning to start a fire which they would then store underground in hot ashes for later use.

Nowadays we use fire on a much more controlled and regular basis, but the complex physics and chemistry behind how it works are the same as they have always been. From heat intensity to combustion, you'll find out in this article all about the science behind this powerful phenomenon essential to life.

We'll start small – with what's going on at an atomic level. The process of creating fire, known as combustion, is basically oxidisation occurring very quickly. When a metal such as steel rusts, it is oxidising but not at a fast enough rate to generate fire. To understand how something can oxidise rapidly enough to produce a flame, we need to understand why the atoms want to bond in the first place.

Generally, fire is the burning of an organic substance which contains lots of carbon. Carbon atoms want to bond with oxygen atoms, but they need a little push in order to do so. If we briefly consider photosynthesis, the energy of the Sun is required to split carbon and oxygen atoms apart, as they are so keen on sticking together. However, when they're apart, they want to immediately snap together again, but require a little encouragement. Imagine a ball trying to roll up a hill, which has a deep hole at the top. If the ball is rolled gently against the slope, it doesn't have enough energy

HOW IT WORKS TV
Visit the **How It Works** website to see just how fast a forest fire can spread

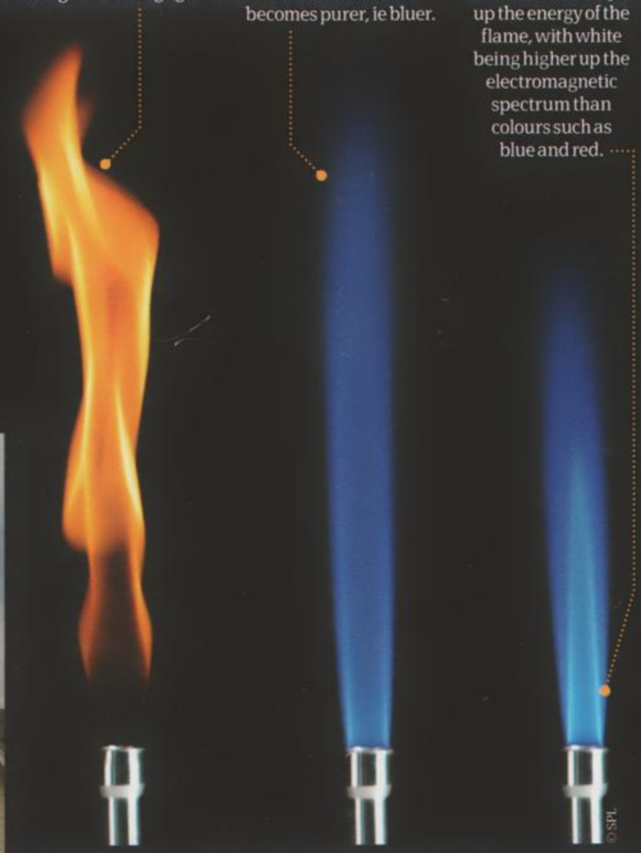
DID YOU KNOW? *Although there were no fatalities, the Great Fire of London in 1666 destroyed over 13,000 buildings*

RED-HOT TO WHITE-HOT

Why do standard flames vary in colour from orange to blue?

The colour of a flame is dictated by the blackbody radiation of the substance that is burning and the oxygen supply to the flame itself. Fire is produced by oxidisation, but as a by-product of the combustion process impurities are often created. The more oxygen present, the less impurities there are. It is these impurities that glow red when hot, causing the fire to burn that well-known orange colour. In addition, the hotter a flame is, the whiter it will become. This is because as things burn at a hotter temperature they move further along the visible spectrum to higher-energy colours such as white, hence the phrase 'white hot'. As a result, white hot is technically hotter than 'red hot'.

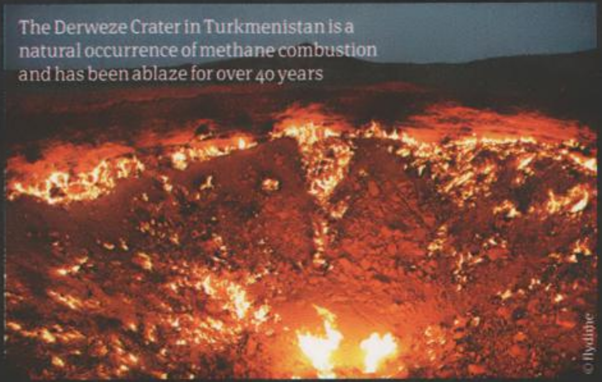
Fire is a devastating force of nature that can reduce entire buildings to smouldering wrecks in mere minutes


Red
The most impure type of combustion, a red flame, will have a lot of impurities present, such as soot, that burn brightly in the fire, causing a red/orange glow.

Blue
If more oxygen is introduced to the flame, less impurities result from the combustion process and thus the flame becomes purer, ie bluer.

White
The hotter a pure flame gets, the closer to white it will become. This is because an increase in heat also bumps up the energy of the flame, with white being higher up the electromagnetic spectrum than colours such as blue and red.

© SPL


The Derweze Crater in Turkmenistan is a natural occurrence of methane combustion and has been ablaze for over 40 years

© flydime

to reach the peak and fall into the hole, but if it is given a big enough push (ie enough energy), it reaches the top and immediately drops into the hole. This is essentially how carbon and oxygen atoms interact. Normally they exist near each other but do not mix. However, when a bit of extra power is introduced to the equation, they are suddenly drawn together. Once a carbon and oxygen atom have gained enough energy to 'snap' together, they release a bit of energy in the process. In turn, this allows two other atoms to unite, and two more, and so forth. This eventually leads to a runaway chain reaction and, ultimately, a fire. We'll consider this process in greater depth later.

When these atoms combine to form a new molecule a certain amount of energy is released or absorbed. The amount created in such a reaction is dependent on how fast the atoms can rearrange themselves and, in the case of fire, this process is extremely rapid. In a slower reaction like rusting, although the principles are similar, the rate of oxidisation is so sluggish that the temperature increases by only about one degree Celsius (1.8 degrees Fahrenheit). If you can accelerate this oxidisation rate, though, then you'll suddenly find the amount of energy – and ultimately heat – released also increases; this is combustion. Every substance has a threshold temperature at which the atoms will gain the necessary power to snap together and start a runaway chain reaction, and once this temperature is passed then combustion can begin. If heat cannot dissipate faster than it is created, combustion is all but inevitable.

Understanding what's going on during combustion can be difficult to comprehend, so we'll use the relatively ▶

QUICK-FIRE QUESTIONS

Q: HOW FAST IS FIRE?

Although estimates vary largely, most fires (in particular forest fires) are thought to move at about 16-20km/h (10-12mph).

Q: WHAT MAKES THINGS FLAMMABLE?

The instability of a substance's atoms and their likelihood to combine with oxygen are what ultimately determine a material's level of flammability.

Q: HOW DOES FIRE BEHAVE WHEN IN ZERO GRAVITY?

A flame in a zero-gravity environment spreads outwards like a balloon because there is no external force acting on it.

Q: WHY DOES FIRE 'EAT' OXYGEN?

Fire is a rapid process of combustion, which itself is caused by oxidisation, where atoms of oxygen combine with other atoms to make new molecules so fire must consume oxygen.

Q: WHY DO FLAMES FLICKER?

In the absence of a draught disturbing the flame, flickering is the fire searching for more oxygen to keep burning.

> "When fuel is pure fire appears blue, as there are very few impurities"

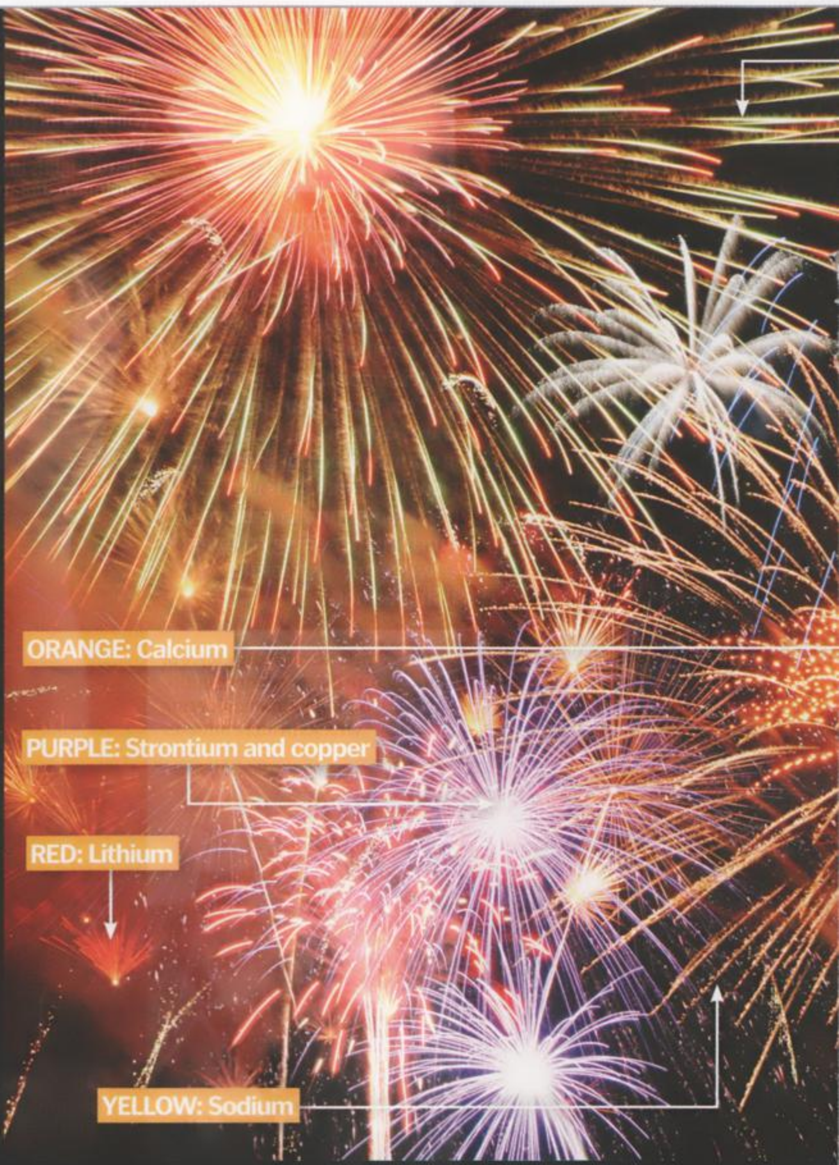
▶ simple example of hydrogen to demonstrate the process. During the combustion of hydrogen, oxygen and hydrogen molecules combine to produce water but, as a by-product of this, heat is also generated. If this heat is greater than the threshold temperature of hydrogen, then another reaction will take place. The rate of combustion in a material is determined by how unstable its atoms are and, in the case of hydrogen and oxygen atoms, they are very unstable. The addition of an external factor such as more atoms or an increase in heat energy will result in a chemical chain reaction taking place as the remaining molecules bond together.

So now we get on to what fire actually is. It might surprise you, but solids and liquids do not actually burn or, rather, they are not responsible for the visible flames we see. Paper, petrol, or indeed any flammable material, doesn't burn itself, but in fact it is the vapours emanating from these solids and liquids that burn. As an example, let's consider how a candle works.

Melted wax travels up the wick and vaporises when it reaches the top, but it doesn't burn itself. The heat from the flame as the wax reaches the top causes it to vaporise and subsequently oxidise, or burn, in turn releasing more heat. This is the same process with paper and wood. The material vaporises, and this heated vapour oxidises, in turn generating further flames and heat. Not all the carbon combines with oxygen to combust though. Some of the carbon forms other molecules, which are responsible for a flame's glow. Soot, composed mostly of carbon, is formed just before it enters the flame. It is these soot molecules growing superhot that cause fire's characteristic reddish glow.

When fuel is pure fire appears blue, as there are very few impurities. The centre of a flame, as seen in a candle, will often appear blue where there is little other material. Flames that appear red have been overpowered by soot and smoke, which burn bright red under heat, tinting the flame.

The cause of this redness is something known as blackbody radiation. Everything in the universe emits energy, and in some cases this is visible. For example, humans emit infrared energy, so when viewed via night-vision goggles we 'glow'. The measure of the energy an object gives off is known as its blackbody radiation. When something is burning red, it is merely giving off energy corresponding to red on the electromagnetic spectrum. Humans are too cool to burn with this sort of visible light but things like iron, lava and scot in a flame are all able to reach the necessary heat, so they release this visible blackbody radiation. This is why, for the most part, fire appears red when organic substances are feeding it. To learn why some things burn a completely different colour, like purple or gold, see the 'Chemical colours' boxout. ✽



ORANGE: Calcium

PURPLE: Strontium and copper

RED: Lithium

YELLOW: Sodium

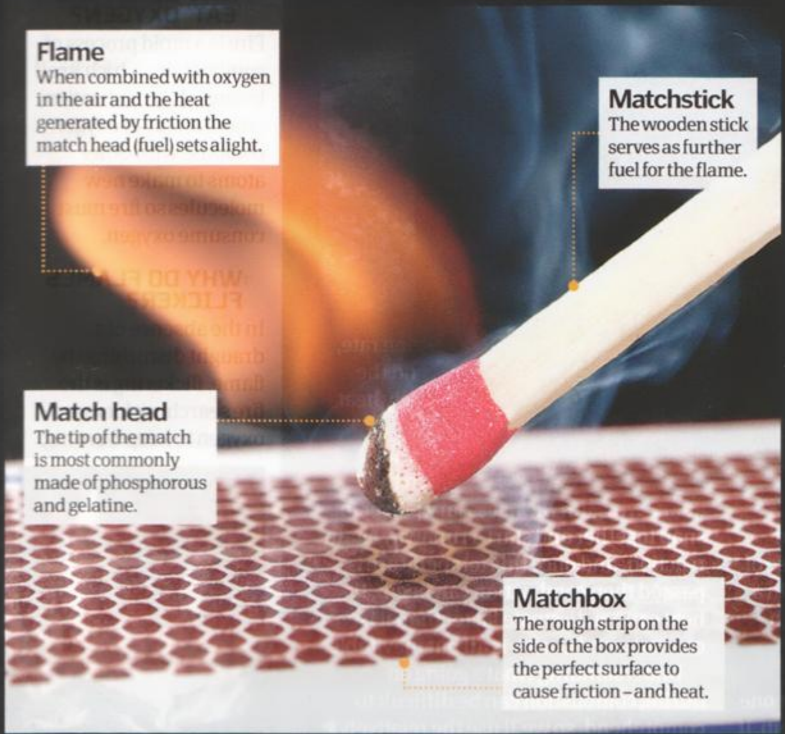
The fire triangle

The essential trio that fire can't do without

For a fire to start – and indeed survive – it requires three things: oxygen, fuel and heat. Let's take the example of striking a match to show how this trio combines to initiate the runaway reaction of combustion.

As you strike the match against the box, the heat produced by friction is higher than the ignition temperature of the tip of the match. The head acts as the fuel, the air contains oxygen and friction causes heat. As the head burns, the fire heats the wooden stick beyond its threshold temperature and causes it to burn too. If the stick were made of, say, metal the match would quickly burn out. In this scenario, once the head had burnt out the fire would no longer have one of its key components – fuel – available, thus it would die.

Fuel, oxygen and heat are needed to both initiate and sustain combustion; this is known as the fire triangle. Each type of fuel has an ignition temperature at which it will rapidly begin uniting with oxygen, ultimately setting alight. With a match, you have two of these three components before it is lit: fuel and oxygen. By rubbing it across a matchbox and creating friction, heat is produced which sparks the chain of reactions in the head of the match and leads to the production of fire. For a match to ignite it needs a temperature of around 182 degrees Centigrade (360 degrees Fahrenheit), which is produced as it travels across a rough surface. Once the match head is ignited, more and more heat is released, resulting in a flame – all in less than a second.



Flame
When combined with oxygen in the air and the heat generated by friction the match head (fuel) sets alight.

Matchstick
The wooden stick serves as further fuel for the flame.

Match head
The tip of the match is most commonly made of phosphorous and gelatine.

Matchbox
The rough strip on the side of the box provides the perfect surface to cause friction – and heat.

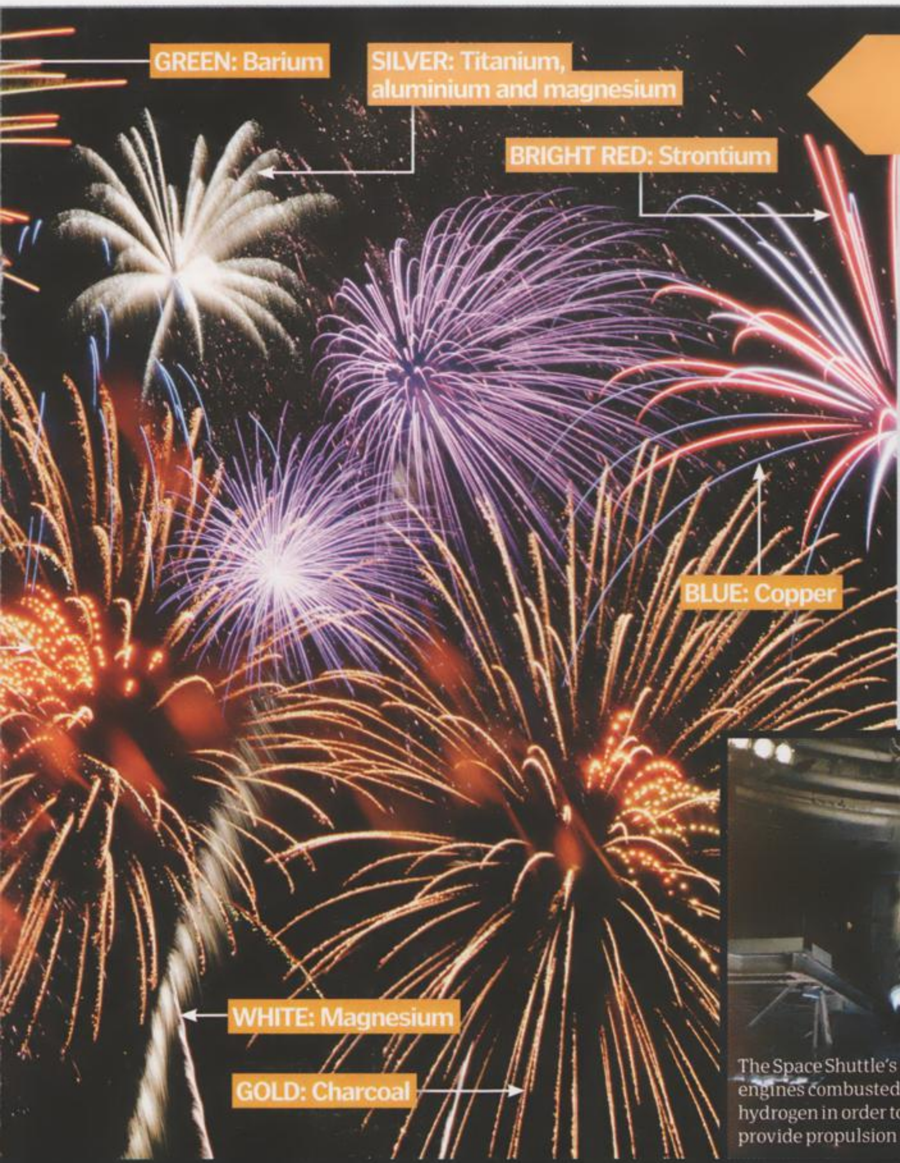
DID YOU KNOW?

© ESO

Big Bang led to biggest temperature

Immediately after the Big Bang, it is thought that the universe was at the maximum hottest temperature possible under the laws of physics. It has been calculated to have been about 140 million trillion trillion degrees Celsius (252 million trillion trillion degrees Fahrenheit). Now that's hot!

DID YOU KNOW? *William the Conqueror enacted a law in 1068 that all fires must be extinguished in the evening*



CHEMICAL COLOURS

Substances burn with varying colours because they have different threshold temperatures at which they burst into flames. Those that require more heat burn towards the white end of the electromagnetic spectrum, as they require greater energy, and vice versa for red. Fireworks are basically just mini 'stars' of fuel that ignite upon the addition of oxygen and heat as per the fire triangle (see boxout).

Light produced from heat is known as incandescence. It is the heat that causes a substance to glow, and as it does so the matter will first emit infrared light (as humans do naturally), followed by red, orange, yellow and white light as it gets hotter. By controlling the level of heat a firework's glow can be manipulated to produce the desired colour/effect.

The Space Shuttle's engines combusted hydrogen in order to provide propulsion

© NASA

QUICK-FIRE QUESTIONS

Q: WHY ARE FLAMES POINTY?

The Earth's gravitational pull is responsible for making hot air rise. It is this convection which shapes flames into their familiar pointed form.

Q: WHAT IS A BACKDRAUGHT?

When a fire has used up all its available oxygen, the surrounding environment can remain hot and airtight until new oxygen is introduced, when a power re-ignition backdraught explosion can occur. This dangerous phenomenon is often seen by firefighters.

Q: WHAT IS SMOKE?

Smoke is the result of volatile organic compounds evaporating from a fire, creating a visible plume of rising gaseous material.

Q: WHY DO THINGS BURN AT DIFFERENT TEMPERATURES?

It's due to the strength of the bonds and the sizes of atoms and molecules in various materials. As you'd expect, stronger, more stable atoms need more energy to combust.

Q: SPONTANEOUS COMBUSTION: IS IT REAL?

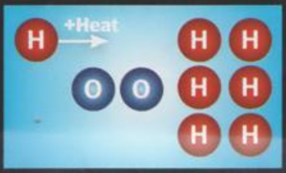
This as-yet-unproven process involves the sudden combustion of an entire object when a heat source is introduced. Its existence is cause for 'hot' debate among scientists.

Combustion How this process can spark an inferno

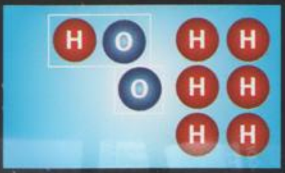
Combustion is the process through which atoms can gain enough energy to surpass their temperature threshold and bond with others to form entirely new molecules.

Energy is released in this process in the form of heat, which, in turn, causes other atoms to bond in similar ways. Essentially, this leads to a runaway chain reaction where many atoms in a material suddenly find themselves with enough energy to exceed their temperature threshold.

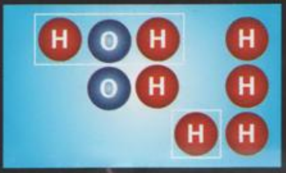
The general rule is, if heat is created faster than it can dissipate, then combustion will occur. Ultimately, a high enough level of sustained combustion will lead to fire.



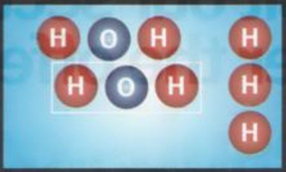
1. Stable
The introduction of energy, such as heat, to a stable mix of oxygen and hydrogen gas can trigger a sudden chain reaction.



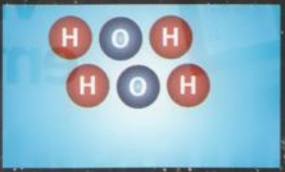
2. Reaction
With enough energy, a hydrogen atom (H) reacts with a molecule of oxygen (O_2), forming one hydroxyl radical (OH) and an oxygen atom (O).



3. Water
The OH molecule reacts with a molecule of hydrogen (H_2), producing a water molecule (H_2O) and a hydrogen atom.



4. Runaway
The atom of oxygen freed earlier reacts with another H_2 to produce a new H_2O molecule and H atom. Steps 2 and 3 then repeat.



5. Combustion
Three freed H atoms react with three O2s, producing nine H atoms, which liberate 27 more and so on. This chain reaction is combustion.

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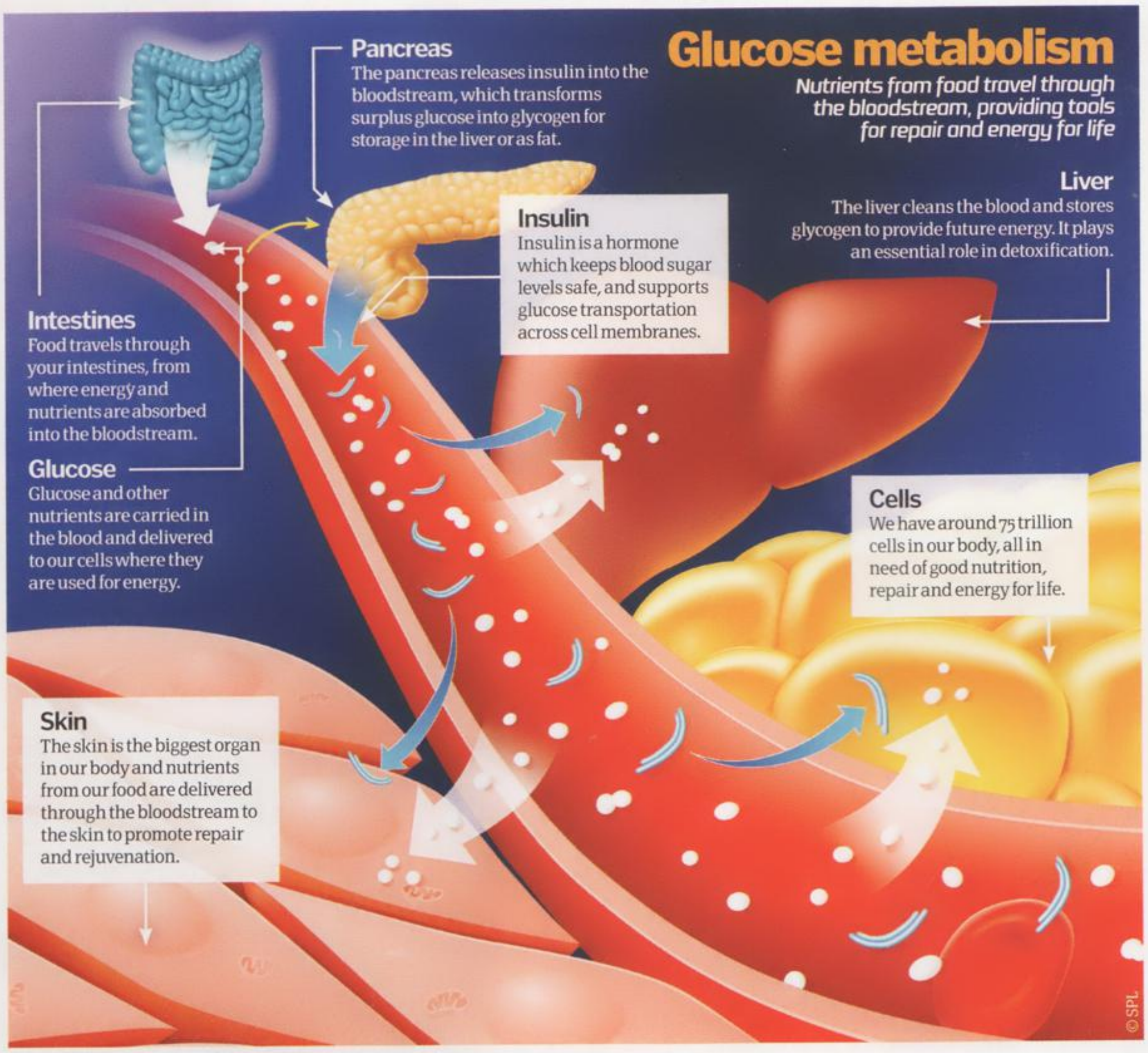
Head to Head ANIMAL METABOLISM

1. Sloth
A sloth's metabolism is so slow that they take an extremely long time to move and digest their food. In fact, they only do a poo once a week!

2. Ants
Ants living in a colony produce just 75 per cent of the metabolic by-products that would be produced by each ant if it were alone.

3. Hummingbird
Hummingbirds have small bodies and very high levels of activity, giving them a metabolic rate approximately 12 times greater than that of a pigeon.

DID YOU KNOW? *When metabolism goes wrong it can result in many diseases including diabetes and enzyme deficiencies*



Glucose metabolism

Nutrients from food travel through the bloodstream, providing tools for repair and energy for life

Pancreas
The pancreas releases insulin into the bloodstream, which transforms surplus glucose into glycogen for storage in the liver or as fat.

Insulin
Insulin is a hormone which keeps blood sugar levels safe, and supports glucose transportation across cell membranes.

Liver
The liver cleans the blood and stores glycogen to provide future energy. It plays an essential role in detoxification.

Intestines
Food travels through your intestines, from where energy and nutrients are absorbed into the bloodstream.

Glucose
Glucose and other nutrients are carried in the blood and delivered to our cells where they are used for energy.

Cells
We have around 75 trillion cells in our body, all in need of good nutrition, repair and energy for life.

Skin
The skin is the biggest organ in our body and nutrients from our food are delivered through the bloodstream to the skin to promote repair and rejuvenation.

© SPL

How fast is your metabolism?

Metabolism doesn't just affect your ability to gain or lose weight

The basal metabolic rate (BMR) measures how fast a person's body uses energy (in calories) while at rest. If you eat too many calories, the body will store the energy as fat for later use. Those with a low BMR burn fewer calories while at rest and will have a tendency to gain weight.

Hormones play a key role in metabolism – eg thyroxine is a hormone produced by the thyroid gland which affects the speed of metabolism. An overactive thyroid can result in energy being used too fast, resulting in hyperactivity and weight loss. The hormone insulin is released by the pancreas in response to elevated blood glucose – usually after meals. It pushes blood sugar into the cells and triggers an increase in anabolic activities.

It's common for people to blame a slow metabolism for their weight problems, but usually this is unsubstantiated and more likely a result of poor diet and lifestyle choices.

How metabolism functions

Metabolism is vital for life – if it stops, you die

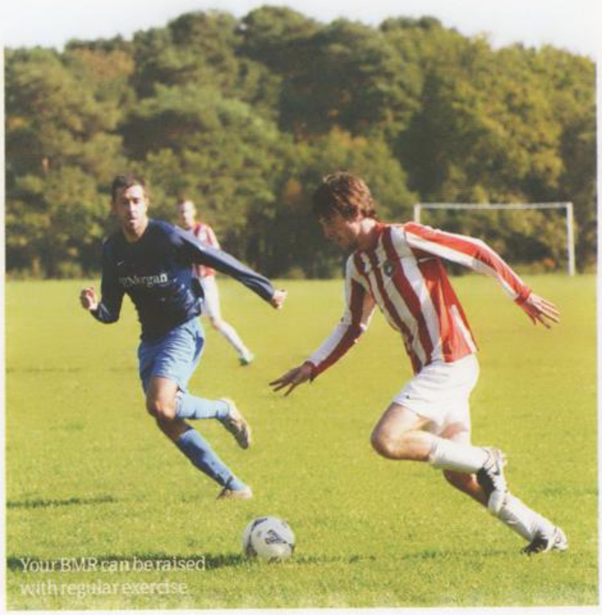
Metabolism is a series of chemical reactions in the body, which convert the food we eat into the energy that we use for growth, movement and healing. Metabolic reactions occur simultaneously to keep us healthy.

Metabolism begins with plants and photosynthesis – the process whereby a plant absorbs energy from sunlight enabling it to create sugars from water and carbon dioxide. We eat the plants, taking in this energy as carbohydrates, which release glucose into the bloodstream to fuel the body. Digestive enzymes break protein from food down into its individual constituents, called amino acids. Fats are converted into fatty acids, and carbohydrates become sugars, all of which are slowly released into the bloodstream as part of the digestive process.

These nutrients enter the body's cells through the blood and are used either to power the body, build muscle and repair damage or are stored for later use. So the process of metabolism is the building up of tissues, muscle and energy stores and the breaking down of energy stores and fat to generate energy when it is required.

Anabolism (constructive metabolism) is all about building and storing: it supports the growth of new cells, the maintenance of body tissues and the storage of energy for use in the future.

The reverse is catabolism (destructive metabolism), which produces energy for cellular activity. Catabolism releases glucose, mostly from carbohydrates and stored fat, which provides energy to heat the body and enable movement on demand.



Your BMR can be raised with regular exercise

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DID YOU KNOW? *The period of time grapes' skins are kept with their contained juice determines the colour of the final wine*

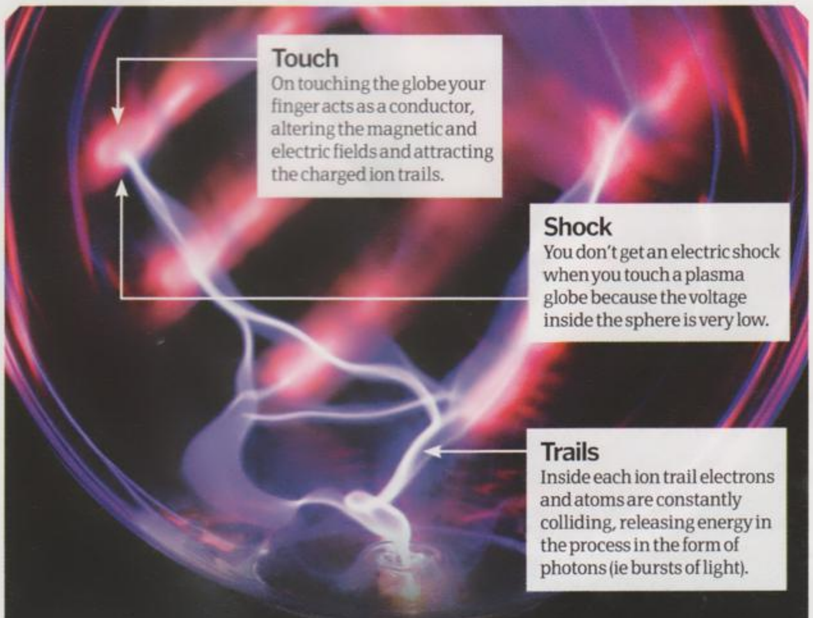
Narcolepsy can also cause cataplexy, hallucinations and sleep paralysis

Narcolepsy explained

What causes those with this condition to suddenly drop off?

Narcolepsy is a sleep disorder caused by a malfunction of the nervous system. It is widely considered to be the result of a deficiency of hypocretin, a chemical in the brain that activates arousal and regulates sleep. Why the deficiency occurs is unknown, but scientists are working on ways of supplementing hypocretin to reduce symptoms.

Narcolepsy is often inherited and symptoms include periods of extreme drowsiness every three to four hours, often resulting in a short nap. Most episodes last just 15 minutes, then they awake refreshed, but periods of sleep can last longer. It's common for those afflicted to fall asleep after meals but it can also happen while driving, talking or at work. Sufferers may hallucinate at the stage between sleep and wakefulness, or experience sleep paralysis, where they are unable to move immediately before or after sleep. Further, during wakefulness, some people experience a sudden loss of muscle tone, called cataplexy. ✽



Touch
On touching the globe your finger acts as a conductor, altering the magnetic and electric fields and attracting the charged ion trails.

Shock
You don't get an electric shock when you touch a plasma globe because the voltage inside the sphere is very low.

Trails
Inside each ion trail electrons and atoms are constantly colliding, releasing energy in the process in the form of photons (ie bursts of light).

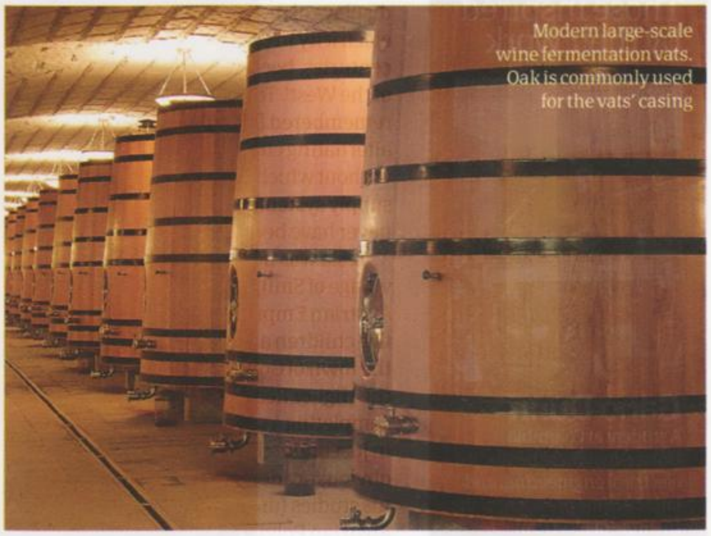
Plasma globes

How do these mesmerising balls of light work?

First invented by Nikola Tesla, the plasma globe has been a popular gadget for many years. The globe, made of glass, is filled with an inert gas such as neon and at its centre is a metal electrode. When a voltage is applied to the electrode (usually through mains electricity or a battery), the electricity jumps between the metal electrode and the outer glass wall, creating an electric field between the two.

The gas inside the globe makes this transition easier and visible. When the electrons have the required amount of energy to jump between the electrode and the glass, they continue to accelerate and gain more than enough energy to ionise the gas.

By doing this they create an ion trail, which other electrons subsequently travel upon. Collisions within the trails between atoms and electrons give off energy in the form of light. The colour of the trails will depend on the type of gas being used in the globe, with gases such as neon and helium giving red and white colours, respectively. ✽



Modern large-scale wine fermentation vats. Oak is commonly used for the vats' casing

Making wine

From grape to plonk, a step-by-step overview of the science of wine

Mass-market wine-making, or viniculture, comprises several major steps.

First, after harvesting, grapes are squashed by a crushing unit, which either maintains or removes the stem and skin depending on the type of wine that is being produced.

Once crushed, the grapes are deposited into a fermentation unit, where primary alcoholic fermentation takes place. Yeast is already present in the grapes to initiate this process, but due to natural yeast generating unpredictable results, cultured yeasts are added too.

Next, the fermentation units undertake temperature-controlled stabilisation, dropping the mixture close to zero degrees Celsius (32 degrees Fahrenheit) to reduce and separate the buildup of tartrate crystals (sediment).

At this point, the wine mix is sent for secondary malolactic fermentation, a process that takes between three and six months. Here proteins within the liquid are broken down and any remaining yeast cells and fine particles dissipate. Finally, preservatives are added to the wine, while

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HEROES OF SCIENCE

HISTORY'S MOST INFLUENTIAL SCIENTISTS

Nikola Tesla

Learn about the life of the man who invented alternating current, and discover why he was a major player in the development of commercial electricity

IN THEIR FOOTSTEPS

Those inspired by their work

Gano Dunn

A student at Columbia University, where he studied electrical engineering, and later became president of the Institute of Electrical Engineers, Gano Dunn was heavily influenced by Tesla. Writing as he assisted Tesla in his experimentations at Columbia, Dunn stated: "Tesla solved the greatest problem in electrical engineering of his time. My contact as [Tesla's] assistant at the historic Columbia University [and] high-frequency lecture afterward, left an indelible impression and an inspiration which has influenced my life."

Nikola Tesla was a Serbian-American inventor, electrical engineer and entrepreneur who, thanks to his wondrous displays of the potential applications of electricity in the late 19th and early 20th centuries, became known as the 'Wizard of the West'. Today he is most famously remembered for his invention of practical alternating current (AC) distribution, without which the advanced electrical supply systems we have today would never have been possible.

Tesla was born in the small, remote village of Smiljan in the now-defunct Austrian Empire. Nikola was the fourth of five children and, as his family moved to the town of Gospic in 1862, he enrolled at the Higher Real Gymnasium in Karlovac, completing a scheduled four-year course in just under three years. Due to his obvious academic aptitude, he carried his studies further, enrolling at the Austrian Polytechnic in Graz in 1875, where he read electrical engineering and specialised in the field of the yet-to-be-established alternating current.

It was at the Austrian Polytechnic that he became known for his photographic memory and almost synesthesian ability to envision an item upon hearing its name in incredibly fine detail. Interestingly, Tesla later reported in his autobiography that he frequently received visions during blinding flashes that would provide solutions to particular problems he was having.

After studying he moved to Budapest, Hungary, in 1881 to work for the National Telephone Company, becoming the chief engineer. He later became responsible for the operation and maintenance of the entire country's telephone network. After this he took up a job at the Continental Edison Company in Paris, France (that of American inventor Thomas Edison), to work on designs to improve their electronic equipment and distribution systems. According to Tesla's autobiography, it was in Paris that he first conceived the induction motor.

Due to his successes in Paris he was moved by Edison to the Edison Machine Works company in New York City, USA. Tesla was offered the task of completely redesigning the company's existing direct current (DC) generators to AC versions, something Tesla had already spent a long time developing. Reportedly, Tesla was offered $50,000 if he successfully completed this task and, upon presenting a new system to Edison, inquired about his payment. Edison is reported to have broken his word to Tesla, insisting that he had been joking.

Tesla proceeded to leave Edison Machine Works – marking the start of a bitter rivalry between Edison and himself – and set up his own company, Tesla Electric Light and Manufacturing, in 1886. The next year he built his first AC induction motor and in 1888 he demonstrated it to the American Institute of Electrical Engineers. After this success

© Science Photo Library

A life's work

1856
Tesla is born in the Serbian village of Smiljan, which is today located in Croatia.

1862
His family moves to Gospic and Nikola attends the Higher Real Gymnasium in Karlovac.

1875
Studies electrical engineering at the Austrian Polytechnic, Graz, where he begins his work on AC.

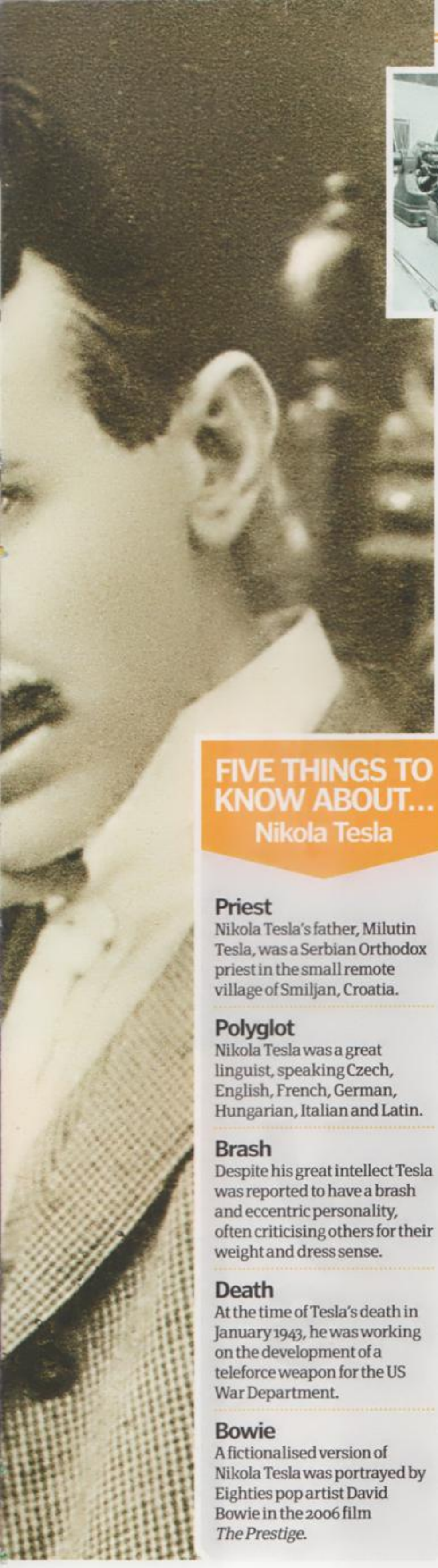
1880
Continuing his education, Tesla enrols at Charles-Ferdinand University in Prague.

1881
Starts working at the National Telephone Company, Budapest. He goes on to become Hungary's chief telephone engineer.

1882
Moving to Paris, France, Nikola works as an engineer for the Continental Edison Company, where he makes improvements to electrical equipment.

1886
Tesla forms his own company to produce an AC motor. His investors fall out with him though and he leaves.

1887
Produces his first brushless AC induction motor, which he shows to the American Institute of Electrical Engineering. He also makes the first Tesla coil.



FIVE THINGS TO KNOW ABOUT… Nikola Tesla

Priest
Nikola Tesla's father, Milutin Tesla, was a Serbian Orthodox priest in the small remote village of Smiljan, Croatia.

Polyglot
Nikola Tesla was a great linguist, speaking Czech, English, French, German, Hungarian, Italian and Latin.

Brash
Despite his great intellect Tesla was reported to have a brash and eccentric personality, often criticising others for their weight and dress sense.

Death
At the time of Tesla's death in January 1943, he was working on the development of a teleforce weapon for the US War Department.

Bowie
A fictionalised version of Nikola Tesla was portrayed by Eighties pop artist David Bowie in the 2006 film *The Prestige*.

Left: Tesla's Polyphase alternating current exhibit at the 1893 World Columbian Exposition

> "Thanks to his wondrous displays he became known as the 'Wizard of the West'"

he joined with George Westinghouse, owner of the Westinghouse Electric & Manufacturing Company, and began to develop a polyphase electrical transmission system that would allow alternating current to be distributed over far greater distances than Edison's current DC systems. Thanks to the stable backing of Westinghouse and Tesla's in-depth knowledge of the field, soon alternating current was widely accepted as the superior distribution system (see 'The big idea' boxout).

In what is now remembered as the most high-profile and stable of Tesla's ventures, he then moved to Colorado Springs, CO, to set up a new laboratory. Here from 1899 onwards he undertook numerous wireless telegraphy experiments that led him to the development of artificial lightning, the discovery of the fact that the Earth itself is a conductor, the formation of the 'Tesla effect' and the acquisition of a number of patents regarding the wireless transmission of power.

Despite continuing to make major discoveries in physics – leading to him being nominated for a Nobel Prize three times – Tesla, due to financial difficulties, spent the latter part of his career attempting to create charged-particle beam weaponry for the United States, who had tasked him with creating a 'death ray'. He never finished the project that he claimed would 'put an end to all war' and went into semi-retirement, formulating many theoretical projects and ideas that never came to fruition.

Nikola Tesla died on 7 January 1943, aged 86, in the New Yorker Hotel suite he had lived and worked in for the last ten years of his life. A state funeral was attended by over 2,000 people, including many eminent scientists and scholars.

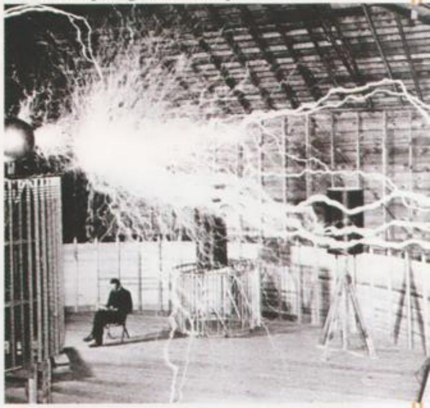
THE BIG IDEA Alternating current

Tesla's most-famous innovation explained

During the 1880s the 'War of Currents' took place between Thomas Edison and Nikola Tesla, the latter working for the Westinghouse Electric Company. For years Edison had expounded his own DC lamps and motors, and had openly criticised Tesla's AC systems as 'utterly impractical'. Edison's system consisted of generating plants feeding heavy distribution conductors, with consumer loads such as lights and motors relayed off them. This system worked but had the severe limitation that all generators needed to be located within about 1.6 kilometres (one mile) of the load.

However, after years of research and the financial backing of Westinghouse, Tesla created an AC system where a transformer was introduced between the generators and customer loads, allowing power to be transmitted at much higher voltages and, more crucially, over far greater distances. After demonstrating the advantages of his new AC system, Tesla won the war and DC systems were phased out over the next century.

A publicity shot of Nikola Tesla in his Colorado Springs laboratory



1888
Begins experimenting with X-rays using single-terminal vacuum tubes and Tesla coils.

1891
Demonstrates wireless energy transmission for the first time, which is termed the 'Tesla effect'. He also establishes his Houston Street lab in New York.

1892
He is made vice-president of the American Institute of Electrical Engineers.

1895
Tesla creates his first ever Tesla generator.

1899
Moves to Colorado Springs and sets up a lab. He carries out various wireless transmission-reception experiments.

1900
With a grant of $150,000, Tesla begins building the Wardenclyffe Tower facility. Here he hoped to demonstrate wireless telecommunications across the Atlantic, but it's not completed due to a lack of funding.

1912
Tesla is tipped to win the Nobel Prize in Physics for his work on tuned circuits using high-voltage, high-resonant transformers.

1917
Receives the highest honour from the AIEE – ironically the Edison Medal.

1931
On his 75th birthday Tesla is put on the cover of *TIME Magazine*, celebrating his achievements.

1937
Tesla publishes a treatise on the feasibility and potential applications of charged-particle beams, describing a superweapon that 'would put an end to all war'.

1943
He dies after a heart thrombus on 7 January 1943. He was in room 3327 of the New Yorker Hotel.

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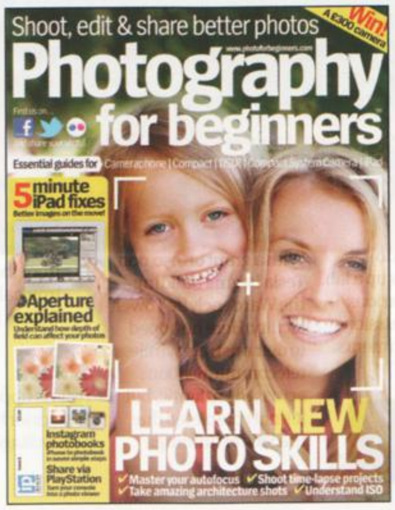
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DID YOU KNOW? *Children from the ages of 3-12 and pregnant women are most likely to experience motion sickness*

Hand warmers

How does science keep your hands toasty?

Hand-warming pads use a solution inside a closed environment with a high freezing temperature to provide a warming effect. A hand warmer starts out at room temperature but, when a metal disc is pressed into the solution, an exothermic reaction is triggered, releasing heat.

Basically, hand warmers use a solution of water and another substance, like sodium acetate. The latter raises the freezing temperature of the solution. In this instance, sodium acetate freezes at 54 degrees Celsius (130 degrees Fahrenheit) but can exist as a supercool liquid with water at a much lower temperature until the crystallisation (or freezing) process is initiated. When the metal disc in the hand warmer is pressed into the supersaturated solution, a few of the molecules of the solution jump into a solid frozen state, in turn causing the rest of the liquid to solidify. This makes the liquid leap to sodium acetate's freezing temperature. By heating the hand warmer further the frozen sodium acetate will melt, allowing it to again be stored as a supercool liquid until its next use.

Chemical hand warmers can be stored at room temperature and below, but will warm when a metal disc is pressed into the solution

Motion sickness, also known as kinetosis, can affect all of us at some point in our lives

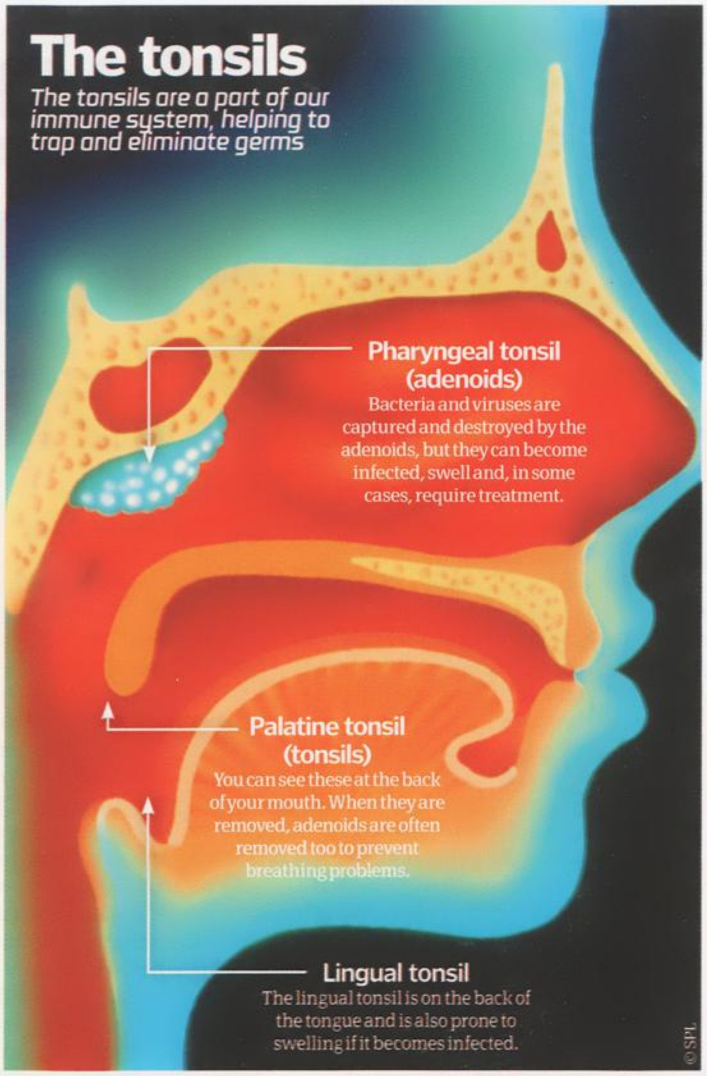
© SPL

Motion sickness

Balancing what your eyes see with what your ears sense can be tricky when you're on the move

A collection of nerves, channels and fluid called the vestibular system inside your ears co-ordinates equilibrium by detecting motion from sensory inputs when moving. When you shift your position, the fluid in your ear also moves, triggering nerve messages that – along with visual information from the eyes – tell the brain what's going on so it can react.

However, when travelling in a coach or on a boat, for example, the atypical motion experienced by the human body can cause an imbalance between what the eyes are seeing (or perhaps what they aren't seeing) and what the ears are experiencing physically. The sensory confusion between the ears, eyes and brain can cause nausea, dizziness and/or vomiting because the brain can detect motion but not necessarily see it. This can also happen in reverse whereby the eyes may perceive movement visually while none is actually felt by the vestibular system, providing the brain with conflicting information that can't be processed quick enough to enable the body to respond and maintain balance.



The tonsils

The tonsils are a part of our immune system, helping to trap and eliminate germs

Pharyngeal tonsil (adenoids)
Bacteria and viruses are captured and destroyed by the adenoids, but they can become infected, swell and, in some cases, require treatment.

Palatine tonsil (tonsils)
You can see these at the back of your mouth. When they are removed, adenoids are often removed too to prevent breathing problems.

Lingual tonsil
The lingual tonsil is on the back of the tongue and is also prone to swelling if it becomes infected.

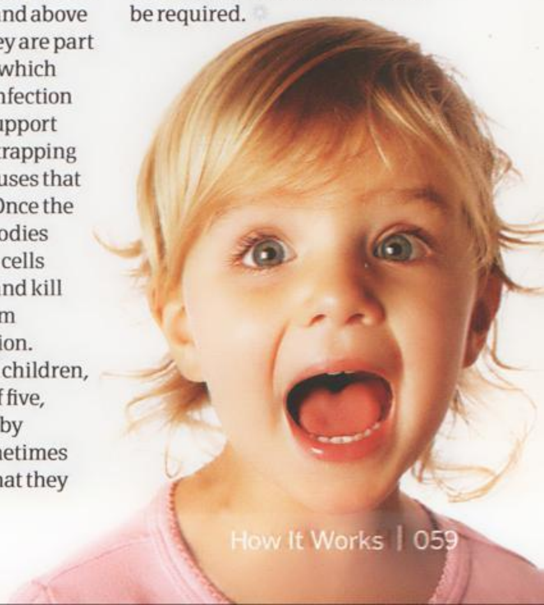
© SPL

Adenoid glands

These germ-busting soldiers prevent nasty bugs from causing an infection

Adenoids are lumpy clusters of spongy tissue at the back of the nasal cavity and above the roof of the mouth. They are part of the lymphatic system, which helps your body to fight infection and detoxify. Adenoids support your immune system by trapping harmful bacteria and viruses that you breathe or swallow. Once the germs are trapped, antibodies produced by white blood cells identify them as foreign and kill them to prevent them from developing into an infection.

They are important for children, but shrink after the age of five, practically disappearing by adulthood. Adenoids sometimes get so covered in germs that they become infected and swell. If this doesn't settle down naturally then treatment for the infection may be required.



> "Cartilage cushions the bones as they move and acts as a shock absorber"

How the shoulder joint works

Bones and muscles work in perfect harmony to enable the wide range of movement our arms enjoy

Bones are like levers: this was the conclusion drawn by Italian physician, Giovanni Alfonso Borelli, when he was studying the human skeleton to see how it worked in the 17th century. He applied mechanical principles, showing that bones and joints work as levers, powered by muscles.

Today, we have a much more detailed understanding of how the body works, and the shoulder joint is a particularly interesting and complex arrangement, comprising the upper arm bone (humerus), the shoulder blade (scapula) and the collar bone (clavicle) – the last two of which form the roof of the shoulder.

The shoulder has three joints that work together to allow arm movement; the main one is the glenohumeral joint, a synovial ball and socket type. The rounded head of one bone fits into the cup-like cavity of another. This allows the greatest range of movement of any joint in the human body.

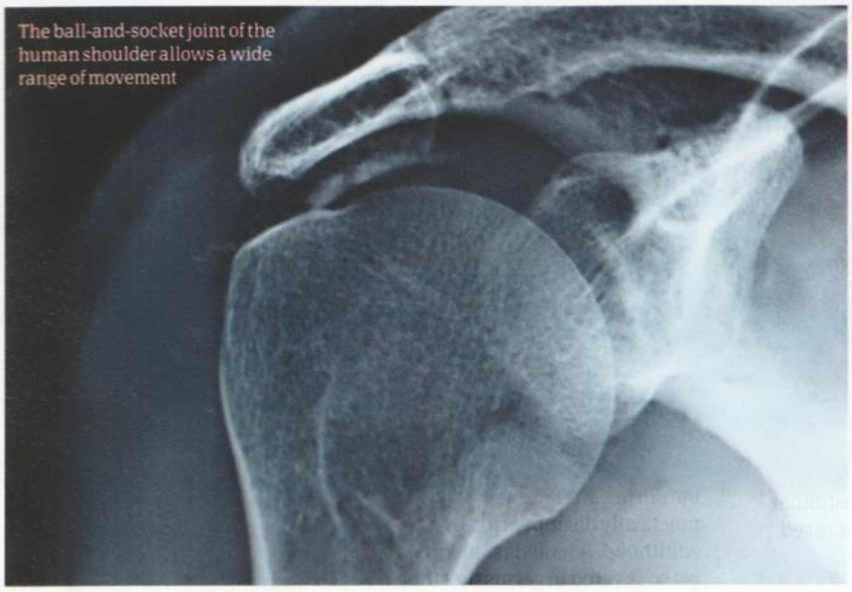
The others are called the scapulothoracic joint (between the shoulder blade and ribs), and the acromioclavicular joint (between the shoulder blade and the collar bone). Raising the arm above the head requires all three of these to work in unison.

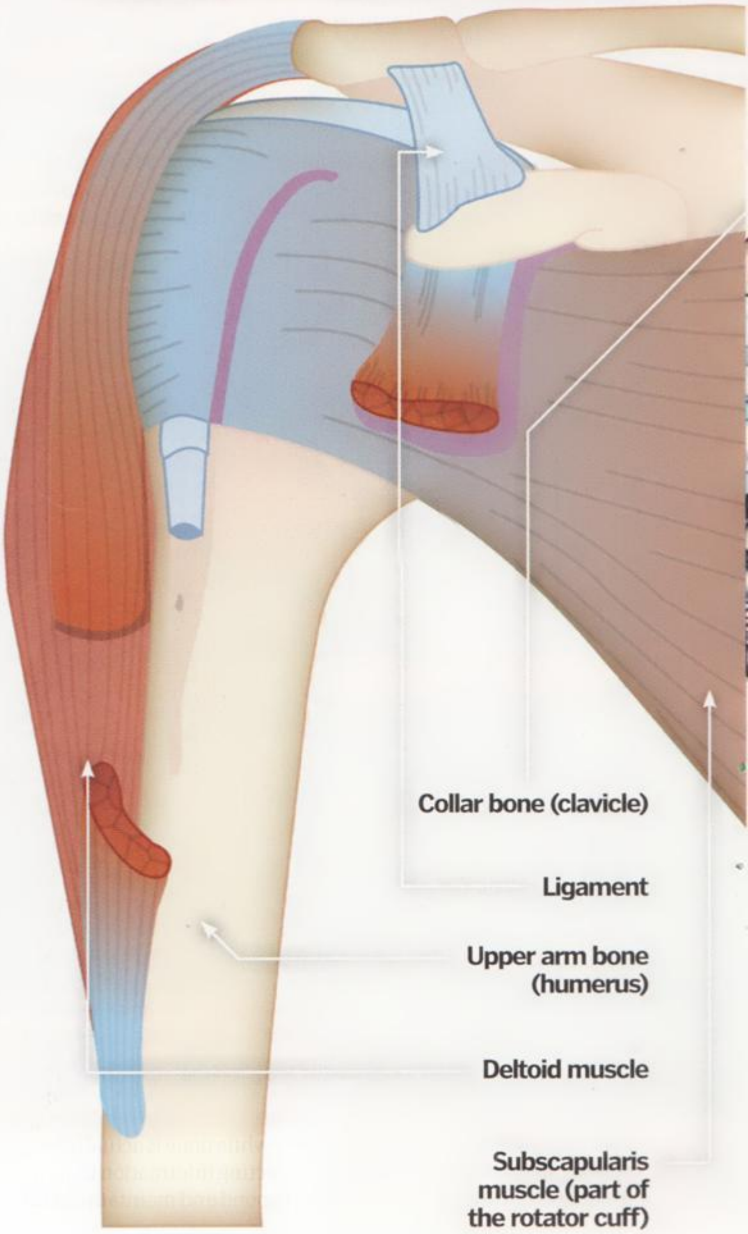
Meanwhile, the deltoid muscle, which covers the shoulder joint, plays an important role in raising the upper arm. Nerve impulses cause the fibres in the anterior and posterior parts of the muscle to balance, while the fibres in the middle contract to draw the arm upwards.

A group of four muscles pull the humerus into the shoulder blade. Together, they are called the rotator cuff, and they stabilise the joint and aid arm rotation. The subscapularis muscle is a part of the rotator cuff and enables your arm to turn inwards.

Within the joint, the ends of the bones are covered by articular cartilage, which cushions them as they move and generally acts as a shock absorber. The whole joint is encased in a fibrous capsule which helps to provide structural integrity. The capsule contains the synovial membrane, a soft tissue that secretes thick synovial fluid into the joint, to nourish the cartilage and keep it slippery.

Such a complex part of the body is prone to injuries, from dislocation to frozen shoulder syndrome


The ball-and-socket joint of the human shoulder allows a wide range of movement



5 TOP FACTS GEN UP ON JOINTS

A bodybuilder's favourite

1 The pectoralis major is a large muscle spanning the front of the chest. It plays a role in movement of the shoulder joint, enabling medial rotation, as well as throwing and lifting.

Shoulder power

2 The strength of the shoulder is a combination of bone density and muscle power. Compared to the hip, there is less bone integrity as the shoulder bones are much shallower.

Joint pain

3 People whose joints are causing them pain can sometimes find relief by taking glucosamine and/or chondroitin tablets, or by swallowing fish oil capsules.

Cartilage care

4 Cartilage is made of collagen and elastin. Vitamin C aids in the formation of collagen in your body, while copper can have a positive effect on the formation of elastin.

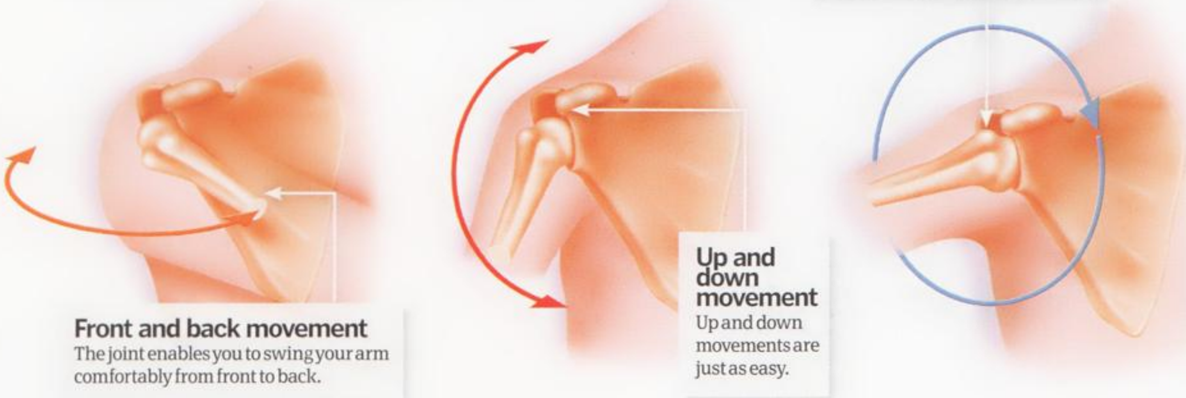
Happy bones

5 Everyone knows calcium is important for bones, but for calcium to be utilised properly, vitamin D is essential – a 20-minute spell in the Sun will boost your vitamin D levels.

DID YOU KNOW? The shoulder blade is not connected to your ribcage but is held in place by fibrous muscle tissue

The ball and socket joint

This joint enables greater movement than any other in the human body



Full circle
You can do a complete circle with this kind of joint – something not possible with any other joint.

Front and back movement
The joint enables you to swing your arm comfortably from front to back.

Up and down movement
Up and down movements are just as easy.

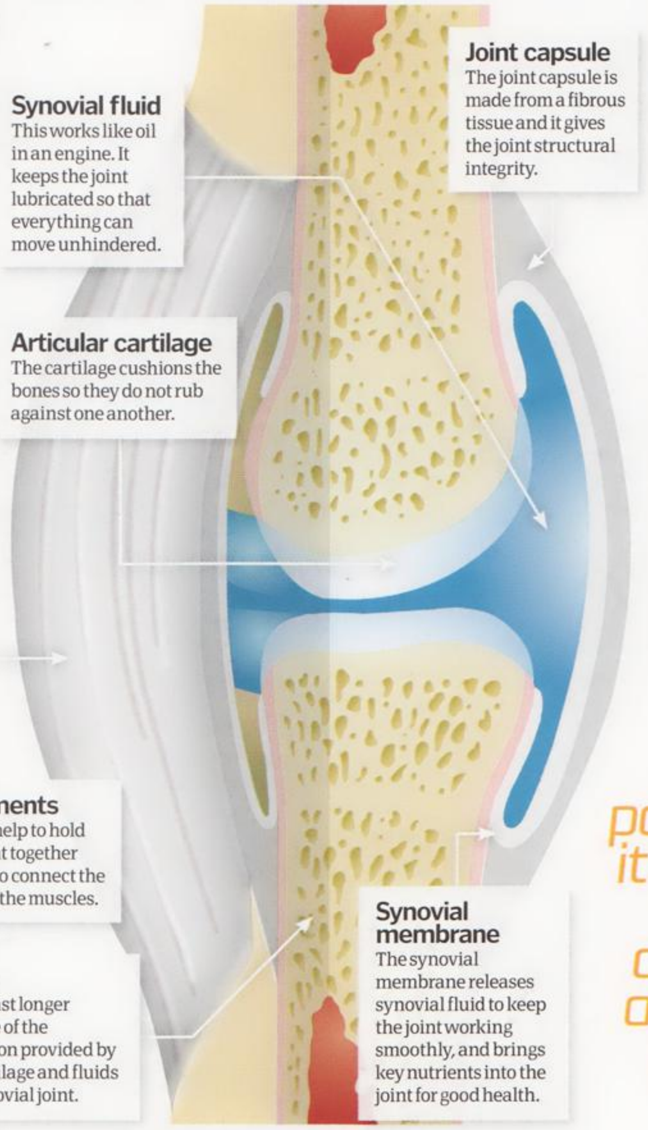
© Science Photo Library

Dislocation

A shoulder dislocation occurs when there is an injury to the joint between the humerus and shoulder blade. The wide range of motion allowed means the glenohumeral joint is not as stable as other joints in the body, making shoulder dislocation relatively common. Such an injury usually occurs after a sporting fall, and often the humerus is found sitting in front of the shoulder blade (an anterior dislocation). Just five per cent of dislocations are posterior dislocations where the humerus is behind the shoulder. Dislocation is extremely painful because it stretches the joint capsule and ligaments, and everything is under huge pressure – there will probably be breaking of tissues and bleeding. Once diagnosed, bones can be put back in place by trained medical staff and anaesthesia is often provided to reduce the pain.

Synovial joint

A synovial joint contains synovial fluid released from a special membrane, all held together within a joint capsule



Joint capsule
The joint capsule is made from a fibrous tissue and it gives the joint structural integrity.

Synovial fluid
This works like oil in an engine. It keeps the joint lubricated so that everything can move unhindered.

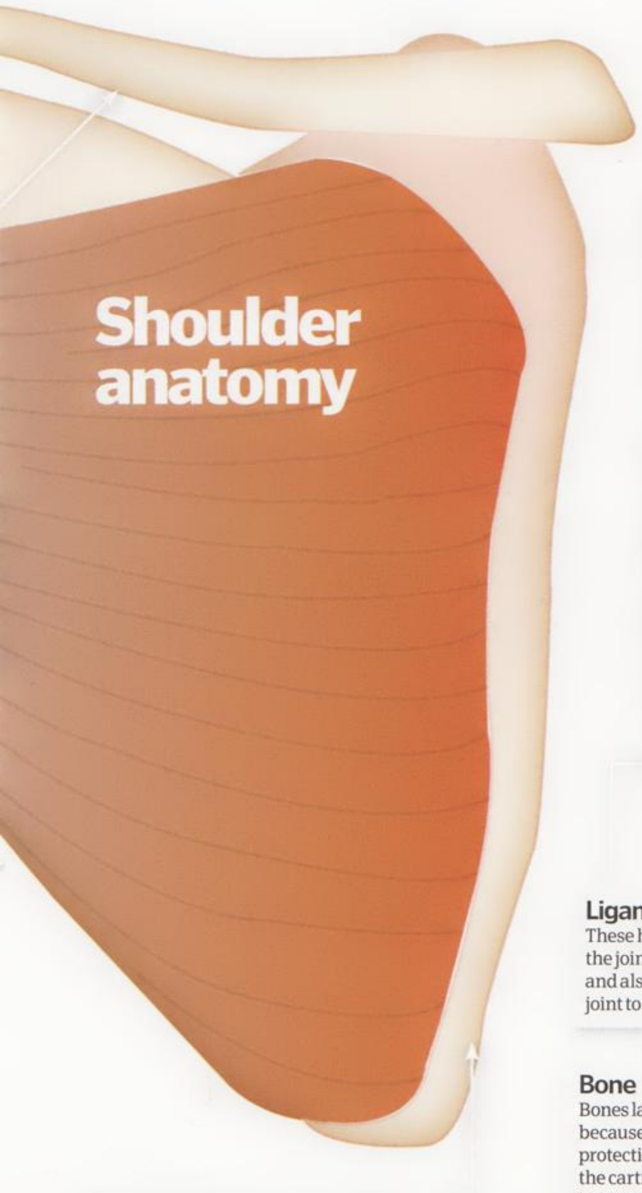
Articular cartilage
The cartilage cushions the bones so they do not rub against one another.

Ligaments
These help to hold the joint together and also connect the joint to the muscles.

Bone
Bones last longer because of the protection provided by the cartilage and fluids in a synovial joint.

Synovial membrane
The synovial membrane releases synovial fluid to keep the joint working smoothly, and brings key nutrients into the joint for good health.

Shoulder anatomy



Shoulder blade (scapula)

> "Dislocation is extremely painful because it stretches the joint capsule and ligaments, and everything is under huge pressure"

Boeing 787 Dreamliner

This new jetliner promises to transform the commercial airliner industry, boasting significantly improved fuel economy and a host of next-gen features. How It Works takes a closer look…

At first glance the brand-new Boeing 787 Dreamliner appears to be nothing special. A new mid-sized jetliner that through its conventional design, standard power output and modest maximum range seems to, for the most part, blend in with the crowd. Just another commercial passenger jet introduced to a market hit severely by the worldwide recession. A multimillion pound piece of technology that changes nothing. But if you believe that, then you couldn't be more wrong…

That is because, as is common with most groundbreaking new technologies and ideas, the devil is in the details. Indeed, the 787 is arguably a slice of the future today, both literally (its service life is predicted to extend up to 2028) and metaphorically. The latter comes courtesy of it being the first aircraft to be designed within a mantra of efficiency over all else. That's not to downplay its numerous improvements and technological advancements in any way – this is one of the most complex jetliners currently in operation – but in the present financial climate and arguably one that will affect the industry for years to come, this greener, cheaper and more accommodating aircraft is laying down a roadmap that others can follow. The evidence for this? How about worldwide orders of 821 planes from 57 operators to the tune of £93 ($145) billion?

So how is the 787 turning the dream of cheaper, more efficient air travel into a reality? The simple answer is a direct 20 per cent saving on both fuel usage and outputted emissions. The long answer is a little more complicated.

The key to the super-high performance granted by the Dreamliner lies in its adoption of a suite of new technologies and materials. Composite materials (ie carbon-fibre/reinforced carbon-fibre plastics) make up 50 per cent of the primary structure of the 787, which include both the fuselage and the wings. These are lighter, stronger and more versatile than traditional pure-metal offerings. Indeed, when this model is compared against the Dreamliner's predecessor, the 777 – read: a mere 12 per cent composite materials and over 50 per cent aluminium – you begin to grasp what a game-changer this vehicle is to the jetliner industry.

The new materials have been partnered with a completely revisited build process, which allows each Dreamliner to be produced from fewer

This month in **Transport**

Transport lovers are in for a treat this issue as we have packed in articles from every field including air, rail, road and sea. Kick off with an in-depth look at the super-efficient 787 Dreamliner then find out about winter tyres, funicular railways, how planes write messages across the sky, rudders and much more.

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TRANSPORT

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5 TOP FACTS BOEING 787 DREAMLINER

Rollout

1 The Boeing 787 Dreamliner was first unveiled on 8 July 2007 in Washington, USA. By the time of its unveiling it had already accrued 677 orders from companies worldwide.

Big brother

2 The 787 is set to have a big brother in 2013, with a larger – read: elongated – variant of the Dreamliner currently in production. This will have a capacity for 290 passengers.

Fat boy

3 The initial assembly of the 787 did not go smoothly, with the aircraft coming in overweight by about 2,300kg (5,000lb). Boeing used lighter titanium to reduce this excess.

Assembly

4 Until 2011, the final assembly of all 787s was at the Boeing factory in Everett, WA. Since last year, however, the aircraft have also been put together at North Charleston, SC.

First

5 The first Dreamliner to be officially delivered was to All Nippon Airways in September 2011. ANA is one of Japan's largest airlines, operating to 35 global locations out of Tokyo.

DID YOU KNOW? The Boeing 787 consumes 20 per cent less fuel than the similarly sized 767

الطيران العماني
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© Boeing

More than 50 companies have worked on the 787, each connected virtually at 135 sites worldwide

© Boeing

787 cabin layouts can be split into one of three configurations, prioritising capacity or class divisions

© Boeing

aluminium sheets, less fasteners (an 80 per cent reduction on the 777) and simpler drill schematics – the latter allowing a 787 to have fewer than 10,000 holes drilled in its fuselage (the 747 needed over 1 million). This saves on production costs, assembly time and streamlines the build, reducing potential points of failure, while increasing aerodynamic efficiency. In addition, more than 60 miles of copper wiring has been eliminated from the new model, again saving weight, plus streamlining the electrical infrastructure.

Talking of electronics, the Dreamliner has been designed with a state-of-the-art, fully electronic architecture, which through the replacement of all bleed air and hydraulic power sources with electrically powered compressors and pumps, extracts as much as 35 per cent less power from its engines at any one time. Further, a new electrothermal wing ice protection system – with moderate heater mats located on wing slats – improves de-icing levels and consistency significantly, again boosting aerodynamic performance. Wing lift performance is also improved thanks to the adoption of raked wingtips, which reduce the thrust needed by the engines.

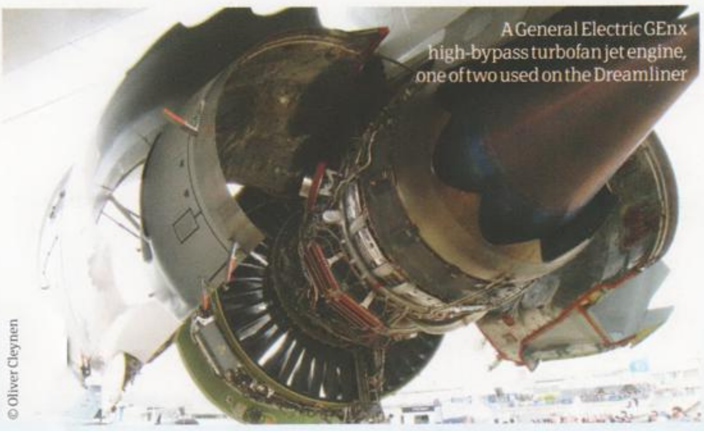
These efficiencies combine with the heart of the Dreamliner: its twin next-generation, high-bypass turbofan engines. Two engine models are used on the 787 – both the General Electric GEnx and Rolls-Royce Trent 1000 – each delivering a maximum thrust of 280 kilonewtons (64,000 pounds force) and a cruise speed of Mach 0.85 (1,041 kilometres/647 miles per hour). Both engines are designed with lightweight composite blades, a swept-back fan and small-diameter hub to maximise airflow and high-pressure ratio – the latter, when complemented by contra-rotating spools, improving efficiency significantly. Finally, both engines are compatible with the Dreamliner's noise-reducing nacelles, duct covers and air-inlets. Indeed, the engines are so advanced that they are considered to be a two-generation improvement over any other commercial passenger jet.

As such, contrary to initial appearances, the Dreamliner is really a wolf in sheep's clothing, delivering standard-bearing improvements, along with a vast list of incremental ones – including energy-saving LED-only lighting – that make it one of the most advanced and future-proofed jets in our skies today. And you know what is most exciting? Judging by Boeing's current substantial backlog of sales, there is a high probability that you will be flying on one of these mighty machines yourself in the very-near future.

The statistics...

Boeing 787 Dreamliner

Crew: 2
Length: 57m (186ft)
Wingspan: 60m (197ft)
Height: 17m (56ft)
Max weight: 228,000kg (502,500lb)
Cruise speed: 1,041km/h (647mph)
Max range: 15,200km (9,440mi)
Max altitude: 13,100m (43,000ft)
Powerplant: 2 x General Electric GEnx / Rolls-Royce Trent 1000


A General Electric GEnx high-bypass turbofan jet engine, one of two used on the Dreamliner

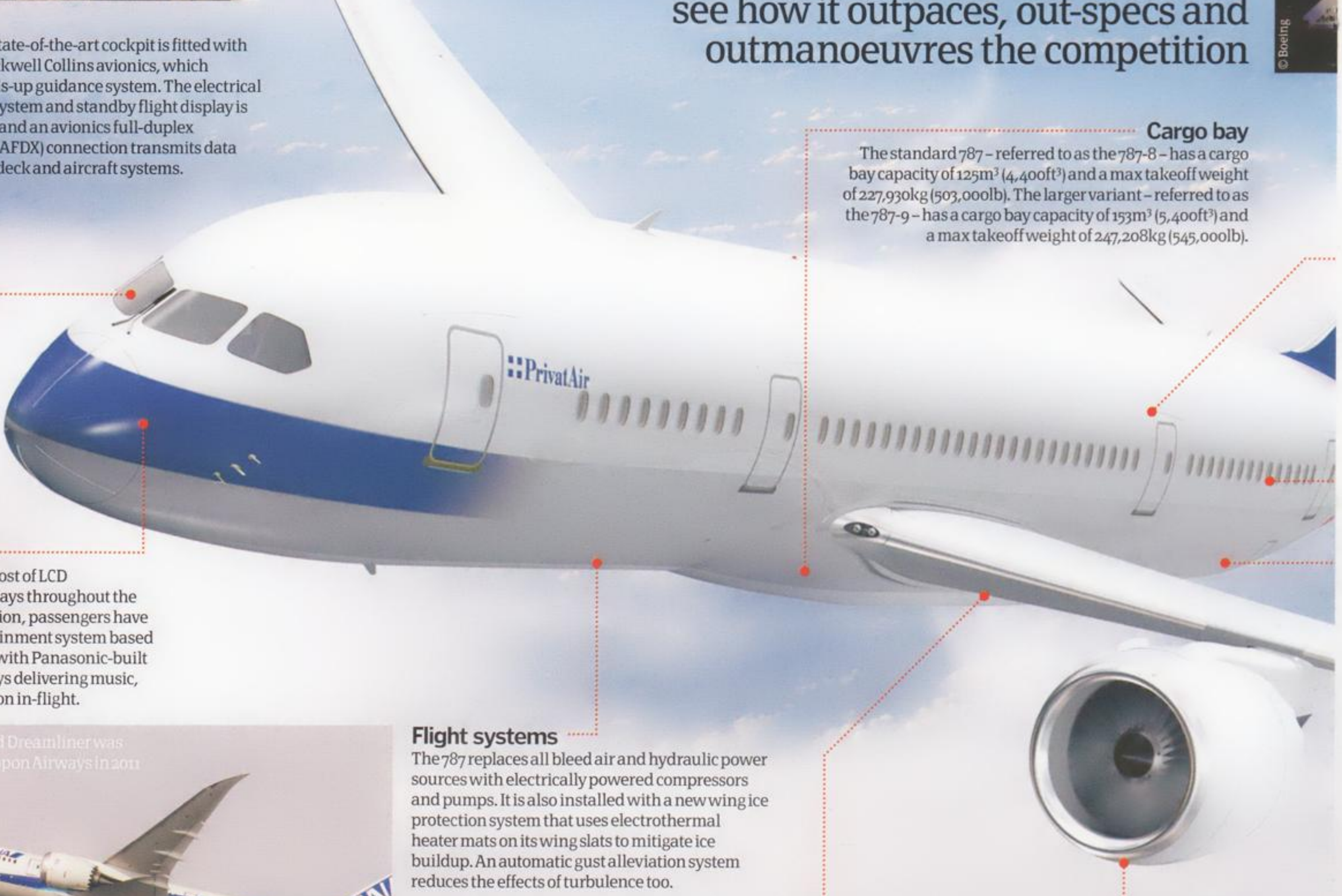
© Oliver Cleynen

"The 787 is constructed from 80 per cent composite materials [carbon fibre and reinforced plastic]"

Anatomy of the Dreamliner

How It Works breaks down a Boeing 787 to see how it outpaces, out-specs and outmanoeuvres the competition

Cockpit
The Dreamliner's state-of-the-art cockpit is fitted with Honeywell and Rockwell Collins avionics, which include a dual heads-up guidance system. The electrical power conversion system and standby flight display is supplied by Thales and an avionics full-duplex switched ethernet (AFDX) connection transmits data between the flight deck and aircraft systems.



Cargo bay
The standard 787 – referred to as the 787-8 – has a cargo bay capacity of $125m^3$ ($4,400ft^3$) and a max takeoff weight of 227,930kg (503,000lb). The larger variant – referred to as the 787-9 – has a cargo bay capacity of $153m^3$ ($5,400ft^3$) and a max takeoff weight of 247,208kg (545,000lb).

Electronics
The 787 features a host of LCD multifunction displays throughout the flight deck. In addition, passengers have access to an entertainment system based on the Android OS, with Panasonic-built touchscreen displays delivering music, movies and television in-flight.

Flight systems
The 787 replaces all bleed air and hydraulic power sources with electrically powered compressors and pumps. It is also installed with a new wing ice protection system that uses electrothermal heater mats on its wing slats to mitigate ice buildup. An automatic gust alleviation system reduces the effects of turbulence too.

Wings
The 787 Dreamliner's wings are manufactured by Mitsubishi Heavy Industries in Japan and feature raked wingtips. The raked tips' primary purpose is to improve climb performance and, as a direct consequence, fuel economy.

Engines
Two engine models are compatible with the Dreamliner: twin General Electric GEnx or Rolls-Royce Trent turbofans. Both models produce 280kN (64,000lbf) and grant the 787 a cruising speed of 1,041km/h (647mph). They are also compatible with the jet's noise-reducing nacelles, duct covers and exhaust rims.

The first completed Dreamliner was delivered to All Nippon Airways in 2011

Evolution of the jetliner

We select some of the high points in the development of the commercial jetliner

1945 Vickers VC.1 Viking
A British short-range airliner derived from the Wellington bomber, the Viking was the first pure jet transport aircraft.

1952 DH-106 Comet
The Comet was the world's first commercial jet airliner to reach production. It was developed by the de Havilland company in England.

1955 SE-210 Caravelle
The most successful first-generation jetliner, the Caravelle was sold en masse throughout Europe and America. It was built by French company Sud Aviation.

1958 Boeing 707-120
The first production model of the now-widespread 707 series, the 707-120 set a new benchmark for passenger aircraft.

1961 Convair 990
A good example of a narrow-body jetliner, the 990 offered faster speeds and greater passenger-holding capacity.

1976 Aérospatiale-BAC Concorde
A standout development in the second generation of jetliners, the Concorde delivered supersonic, transatlantic flight – something unrivalled even to this day.

Head to Head AIRLINER CAPACITY

© Boeing

1. Boeing 787-9
The larger Dreamliner, which is set to be introduced in 2013, can seat up to 290 passengers when it is configured for highest seat quantity.

© Rolf Wallner

2. Boeing 747-400
A significant redevelopment of the 747, the 747-400, when specced out for max number of seats, can carry up to 524 passengers.

© Singapore Airlines-Altair

3. Airbus A380
So big that a new term had to be coined in order to classify it – superjumbo – the A380 has two decks and can carry up to a monumental 853 people!

DID YOU KNOW? To date, over 800 Boeing 787 Dreamliners have been ordered by airlines all around the world

© Boeing

A stand-up, fully stocked bar is available on each 787

Amenities
When on board passengers are offered roomier seats (across all classes), larger storage bins, manually dimmable windows, a stand-up bar, gender-specific lavatories and an on-demand entertainment system. First-class passengers receive a complimentary in-flight meal and, on international flights, fully reclinable seats for sleeping.

Cabin
The standard 787 is designed to seat 242 passengers across a three-class arrangement, with 182 seats in economy, 44 seats in business and 16 seats in first. Cabin interior width rests at 5.5m (18ft) and on either side is lined with a series of 27 x 47cm (11 x 19in) auto-dimming windows.

Fuselage
The 787 is constructed from 80 per cent composite materials (carbon fibre and carbon-fibre reinforced plastic) by volume. In terms of weight, 50 per cent of the materials are composite, 20 per cent aluminium, 15 per cent titanium, 10 per cent steel and 5 per cent other.

© Boeing

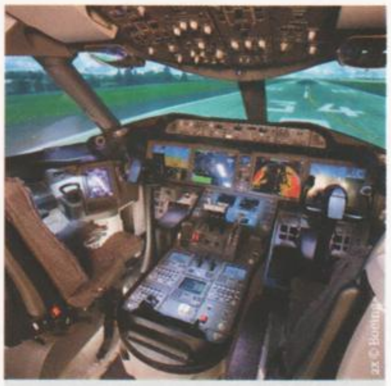
Compatibility
The 787 Dreamliner is designed to be compatible with existing airport layout and taxiing setups. As such the 787 has an effective steering angle of 65 degrees, allowing it to rotate fully within a 42m (138ft)-wide runway. It also has a 32m (100ft) tyre edge-to-turn centre ratio.

1986 Fokker 100
The Fokker 100 was a short-haul specialist that carried up to 100 passengers. Domestic and short-range international flights were its remit.

1994 Boeing 777
The first computer-designed commercial jetliner, the 777 delivered a vast 300-seat capacity and range (17,370km/10,793mi). It became a mainstay of airlines worldwide.

2005 Airbus A380
Since its launch in 2005 the Airbus has been the largest passenger aircraft in the world. The A380 has two decks and, when specced out for all economy-class seating, can carry 853 passengers.

2011 Boeing 787 Dreamliner
The most fuel-efficient jetliner of its class, the 787 has been designed to reduce the cost of air travel, while delivering a range of next-gen tech.


© Boeing

Train to gain

Boeing has gone the extra mile to produce a complete package with the 787 Dreamliner, offering state-of-the-art simulation facilities for pilots to get up to speed

Potential 787 pilots can utilise Boeing's revolutionary full-flight simulator to train for real-world flights and specific context-sensitive scenarios. Currently there are eight 787 training suites at five Boeing campuses worldwide, located from Seattle through to Tokyo, Singapore, Shanghai and on to London Gatwick. The simulators, which are produced by French electronic systems company Thales, include dual heads-up displays (HUDs) and electronic flight bags (EFBs), and are designed to train pilots to become proficient in visual manoeuvres, the instrument landing system (ILS) and non-ILS approaches. Further, missed approaches using integrated specialist navigation, non-standard procedures with emphasis on those affecting handling characteristics, plus wind shear and rejected takeoff training can also be undertaken.

All of the training simulators are approved by the US Federal Aviation Administration (FAA), making them officially some of the most advanced training suites around right now.

Pilots and potential pilots can train at eight simulators worldwide

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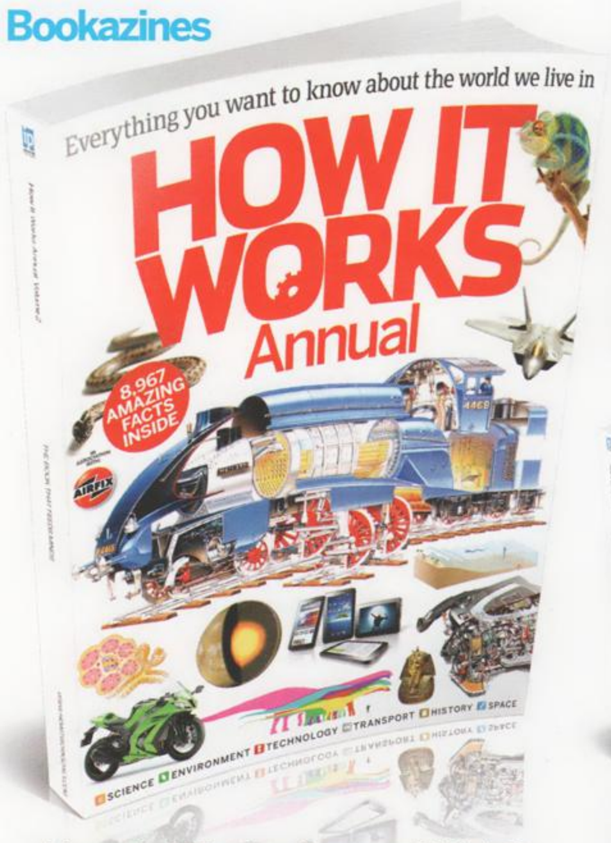
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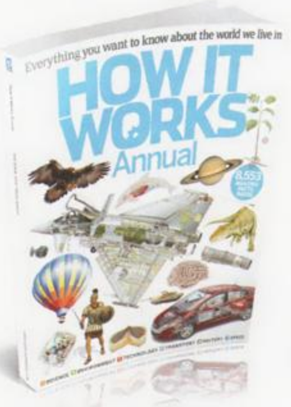
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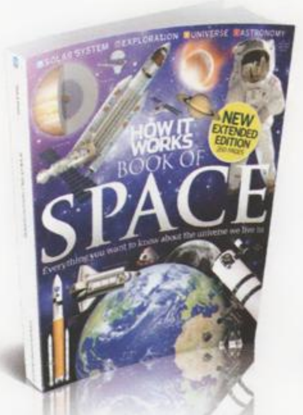
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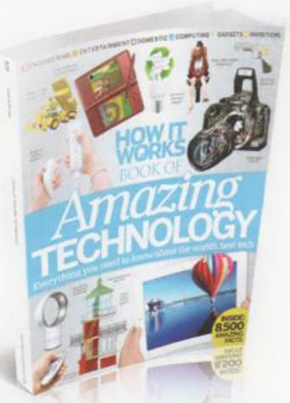
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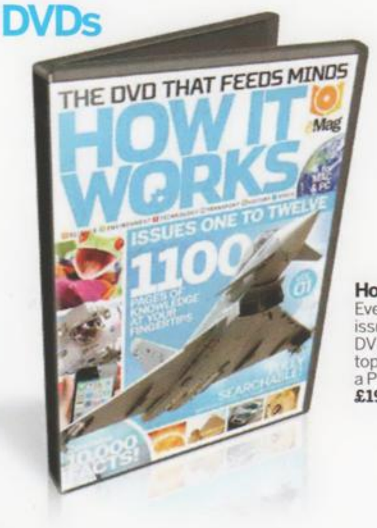
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DID YOU KNOW? The Métro Alpin in Switzerland is the highest funicular railway in the world at 3,456m (11,339ft)

Funicular railways

How do these cliffside vehicles operate?

Funicular railways – also commonly known as incline railways – are typified as two connected rail carriages running over a steeply inclined four, three or two-rail track. Both carriages are connected as they operate under the principle of counterweight. In order to overcome the lack of traction generated by steel rails and tram wheels, but also maintain the minimal rolling resistance they deliver, funicular railways use each of their pair of carriages to power and balance the other over a central, top-mounted pulley.

With this design, very little electrical power is required to haul many tons of carriage up a steep incline, with the only additional power needed to initialise the pulley's motor. The pulley provides enough force to overcome the difference in weight between the two carriages (ie passengers) as well as counteract any friction.

Sailboat rudders

Despite its apparent simplicity, the basic rudder uses complex physics to steer a sailing boat

A rudder is a flat, vertical, blade-like panel submerged in the water. It's usually mounted at the rear of a sailing boat and is hinged so its angle can be altered by a tiller that controls the direction of the rudder. This lever on top of the rudder is operated by the helmsman.

Turning it to one side alters the flow of water over it: the angle causes water to meet it with greater pressure on one side. This imbalance in the drag from the rudder steers the boat because it will turn in the direction of lower pressure.

For example, pulling the tiller to the right will move the boat to the right; water will hit the rudder with increased force on its left side, so the boat will naturally steer right where there is less pressure.

A rudder needs flowing water in order to work. A motionless boat, or one in water with no current, thus can't be steered.

The propellor dictates a boat's speed while the rudder governs its direction

The camshaft ensures your engine runs smoothly and at its peak efficiency

© BMW

What are camshafts?

The smooth running of an engine is dependent on a camshaft which precisely manages the flow of energy that enters and leaves

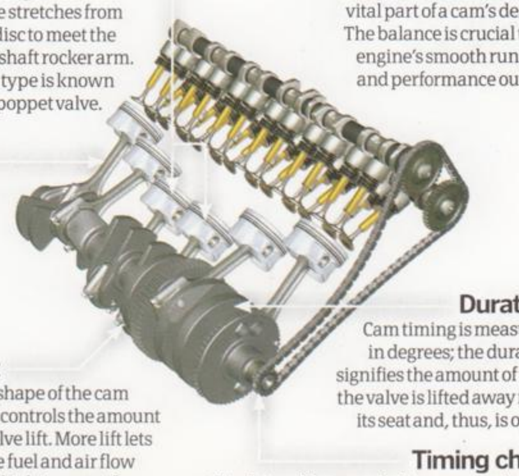
The flow of fuel and air through an engine is controlled by the opening and closing of valves. The timing of this is crucial and is dictated by a camshaft. It is the rotation of this key engine part that forces the valves open and shut at regular intervals.

A camshaft is mounted at the top of the engine. Along its length are lobes, which push on rocker arms as it rotates. At the other end of these are valves, which move up and down as the rocker arms push on them, opening and closing as they move.

The rotation and timing of a camshaft is in turn controlled by the rotation of the crankshaft, the main drive section at the bottom of the engine. A timing chain or belt stretches from the crank to the cam, so that the two move in unison.

Many cars have two sets of inlet and exhaust valves to get more air and fuel in and out of the engine. This requires double overhead cams; the main timing belt drives one cam, with a short intermediate chain connecting the second.

Camshaft in motion



Valve
The long stem of a valve stretches from the disc to meet the camshaft rocker arm. This type is known as a poppet valve.

Overlap
Overlap is where two valves are open at the same time, a vital part of a cam's design. The balance is crucial to an engine's smooth running and performance output.

Duration
Cam timing is measured in degrees; the duration signifies the amount of time the valve is lifted away from its seat and, thus, is open.

Lift
The shape of the cam lobe controls the amount of valve lift. More lift lets more fuel and air flow in, which is a must for performance engines.

Timing chain
The drive of the camshaft is governed by the crank. Drive is transferred via the timing chain.

"The Electronic Warfare Test Facility is designed to re-create a host of natural and manmade environments"

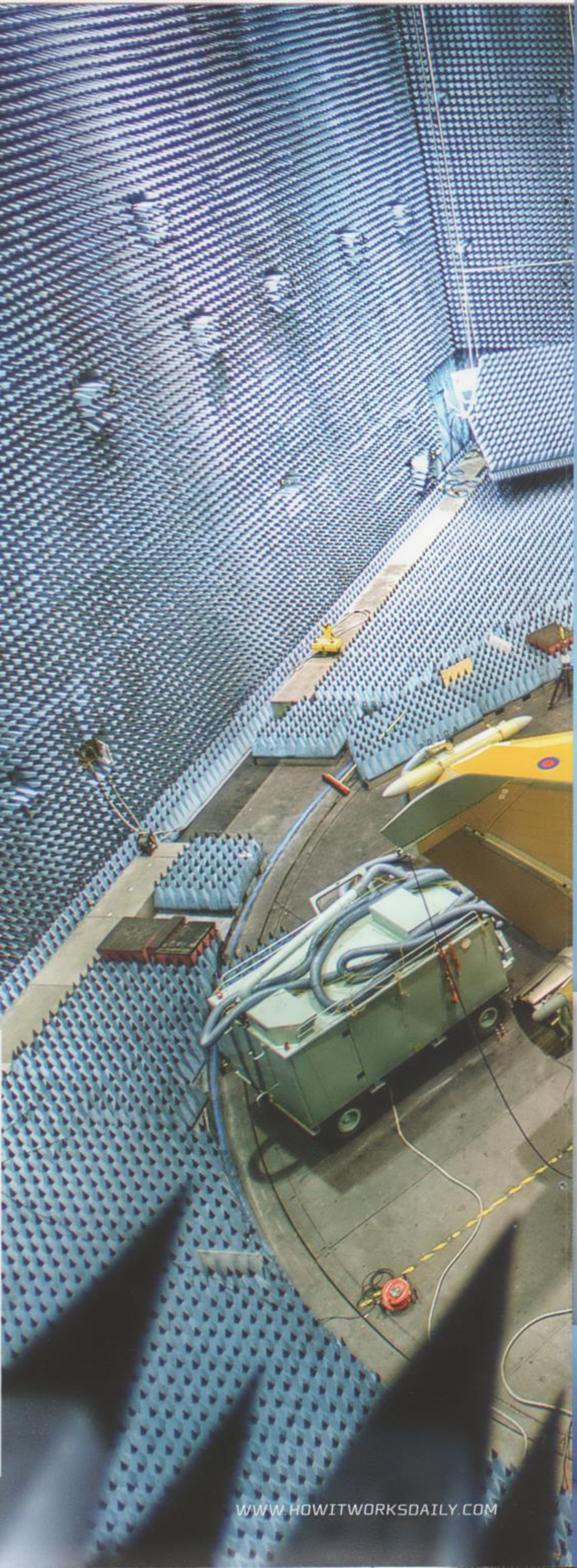
Electronic Warfare Test Facility

BAE's test site for its fighter jet aircraft is truly state of the art, offering an advanced, versatile and whisper-quiet facility to push aircraft to their limits

This impressive image shows BAE's fully integrated Electronic Warfare Test Facility, a vast anechoic (echo-free) chamber (30 x 24 x 13.4 metre/98 x 79 x 44 foot) that is impregnable to electromagnetic interference. It is protected by both a 'classified' location, as well as special jamming materials and a titanic 18-ton steel door, that measures in at 18 metres (59 feet) in height by 11 metres (36 feet) in width.

The facility is designed to re-create a host of natural and manmade environments – such as large cities – something granted by the inclusion of over 20,000 specially coated cones, which allow for diverse electromagnetic testing purposes. As such, the facility is currently used to test the electrical systems of some of the world's most advanced military jets, coming installed with a turntable and comprehensive aircraft hanging array that enable top-tier fighter aircraft, like the pictured Eurofighter Typhoon, to be rigorously put through their paces.

A facility of this nature is necessary today as electromagnetic waves are everywhere in society – produced by everything from mobile phones through to televisions and car radios – and these signals can dramatically interfere with a jet's flight, navigation and weapon systems. By creating a completely isolated environment, BAE has ensured that any plane that leaves the facility has been thoroughly tested for all potential electromagnetic eventualities before it enters service.



A seperate 'hush house' allows BAE to fire a Typhoon fighter jet's engines at full throttle and the noise to remain unheard outside

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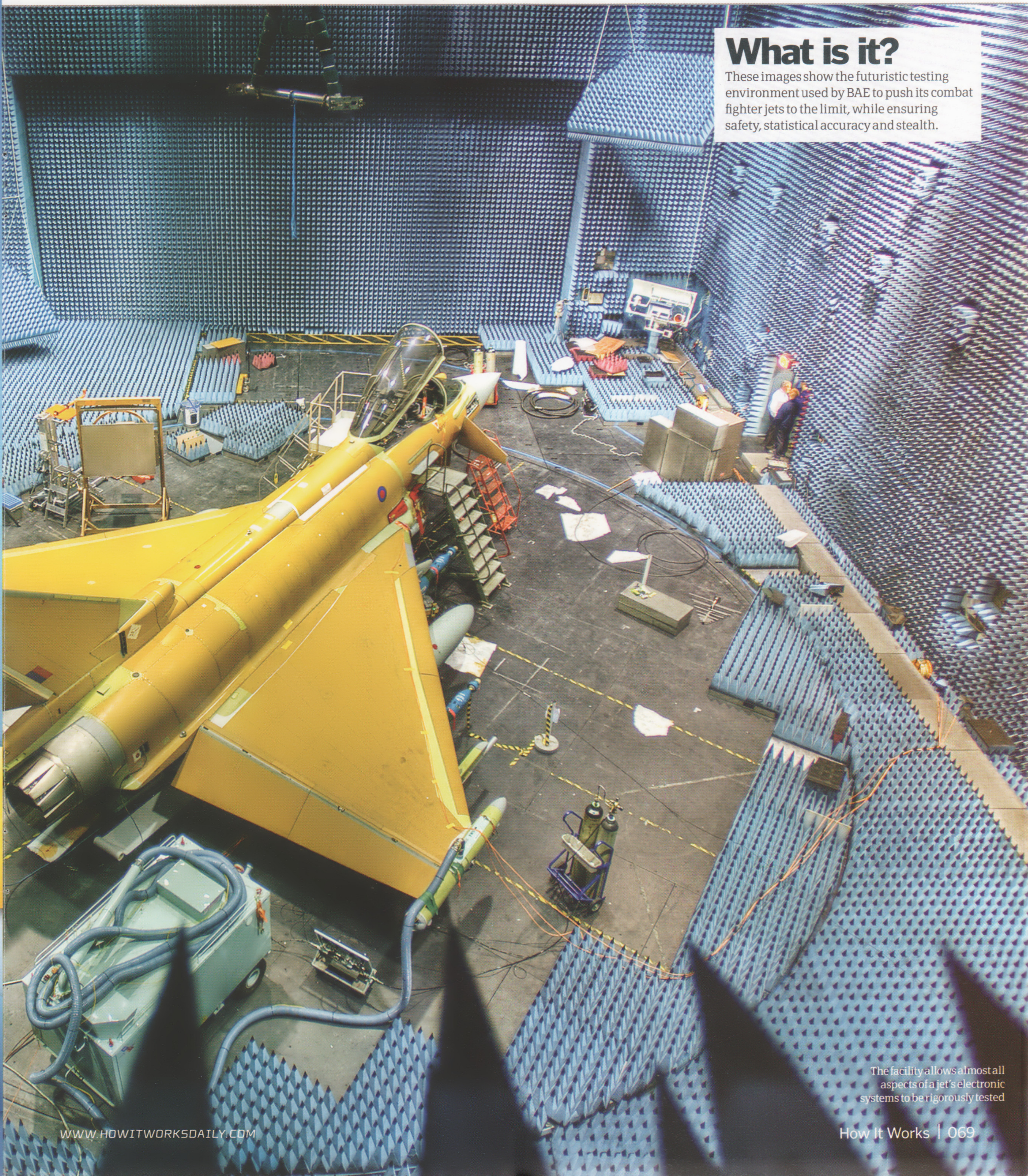
DID YOU KNOW? *The facility can even run a simulation to test how aircraft cope in the event of being struck by lightning*



What is it?

These images show the futuristic testing environment used by BAE to push its combat fighter jets to the limit, while ensuring safety, statistical accuracy and stealth.

The facility allows almost all aspects of a jet's electronic systems to be rigorously tested

> "Winter tyres have smaller tread blocks with far more thin slits"

Winter wheels / Train brakes / Sky messages

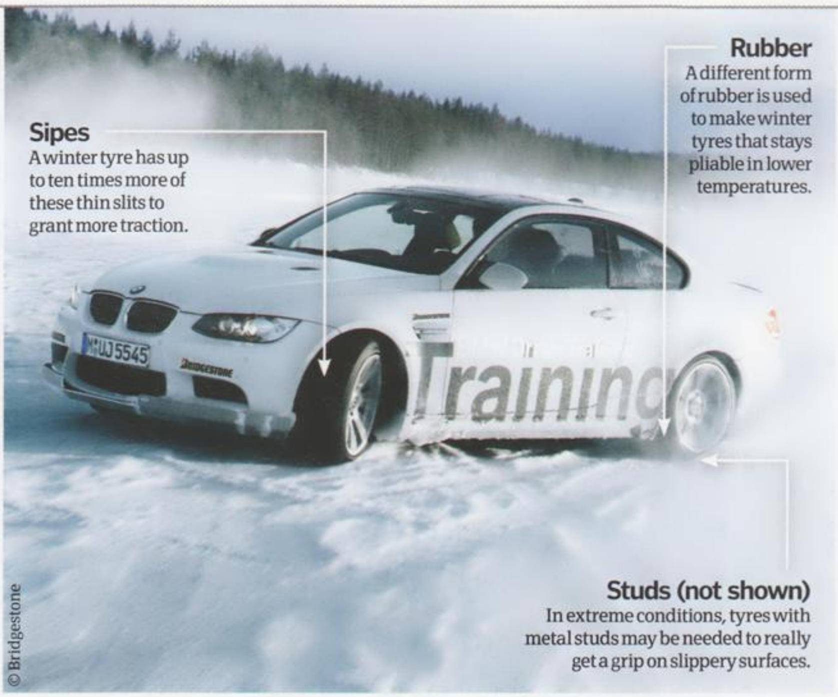
Snow tyres

When the weather turns bad, a winter tyre comes into its own, thanks to physics and clever design

A cold-weather tyre is one that is optimised for winter conditions. When temperatures drop below seven degrees Celsius (45 degrees Fahrenheit), winter tyres are at their most effective – just as the rubber of normal tyres begins to harden and become less efficient. Winter tyres are becoming more popular in the UK and are a legal requirement in some European countries.

Winter tyres have smaller tread blocks with far more thin slits, or sipes, on the surface, to improve traction on slippery roads: a normal tyre has three metres (9.8 feet) of siping whereas a winter tyre has 30 metres (98 feet). The rubber itself is a different formula too with more natural rubber that remains malleable at colder temperatures.

When conditions are really bad, you need snow tyres. These have metal studs in the tread pattern, which cut through snow and ice to give even better grip and traction. It is illegal to use them on the road in certain countries and they should never be mixed with summer tyres.



Sipes
A winter tyre has up to ten times more of these thin slits to grant more traction.

Rubber
A different form of rubber is used to make winter tyres that stays pliable in lower temperatures.

Studs (not shown)
In extreme conditions, tyres with metal studs may be needed to really get a grip on slippery surfaces.

© Bridgestone

One of the most popular requests for skywriting is marriage proposals

How does skywriting work?

The technology and techniques required to write upon the sky

Skywriting is achieved by partnering a lightweight aircraft, typically with a short turning circle, with a special system of pressurised containers and injection pumps. The smoke used to 'paint' a word or symbol onto the sky is generated by the vaporisation of low-viscosity oil in the aeroplane's engine manifold. This oil is held in a pressurised container and pumped when needed – either manually or via a preprogrammed GPS unit – into the manifold to generate smoke for the writing/drawing.

Typically each constructed letter is roughly 1.6 kilometres (one mile) in length and approximately 3.2 kilometres (two miles) above the Earth's surface. An average five-letter word would be painted across 16 kilometres (ten miles) of sky and require more than 15 precisely performed manoeuvres by the pilot.

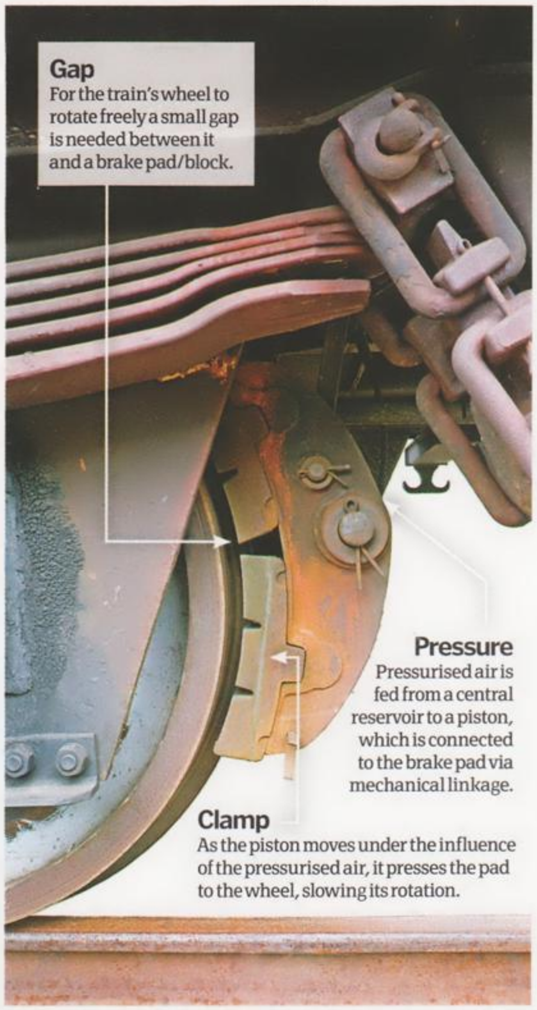
Train brakes explained

How do modern trains come to a stop?

Modern trains, in general, use air brakes to come to a halt. These work by forcing a traditional brake pad or block against the train's wheels in order to convert its kinetic energy into heat via the force of friction, the consequence of which is a reduction in the wheels' rotations-per-minute.

Central to the whole operation is the system's compressed air, which is drawn in from the immediate environment, compressed and circulated from a central reservoir through a piping system. The pressurised air runs through the piping system and pushes on a piston next to each wheel. The piston is attached via mechanical linkage to a wheel's brake pad or block and squeezes against the wheel to slow it. As such, to stop a train the driver need only open a valve connecting the reservoir to the brake pipe and increase the air pressure, thereby engaging the brake pad.

Interestingly, this system can also be used in reverse, with a reduction in air pressure within the piping system used to apply the brakes instead. This technique has become increasingly favoured over the last 20 or so years, as it is perceived as almost fail-safe – ie if pressure is lost for whatever reason, the train can still come to a halt without having to rely on emergency systems.



Gap
For the train's wheel to rotate freely a small gap is needed between it and a brake pad/block.

Pressure
Pressurised air is fed from a central reservoir to a piston, which is connected to the brake pad via mechanical linkage.

Clamp
As the piston moves under the influence of the pressurised air, it presses the pad to the wheel, slowing its rotation.

5 TOP FACTS US NAVY SEALS

Vietnam

1 The US Navy SEALs were initiated officially on 1 January 1962. They were a response to America's need for guerrilla and counter-guerrilla operations during the Vietnam War.

War

2 The SEALs have been involved in all major American conflicts over the past 50 years, seeing action in Vietnam, Grenada, the Persian Gulf, Panama and Afghanistan, to name a few.

Nuclear

3 The majority of SEAL delivery vehicles are launched off the top of nuclear submarines. The SDVs are carried in dry deck shelters and are extracted by SEALs manually underwater.

Roles

4 The four primary roles of an SDV are to enable combat swimmer attacks, reconnaissance and surveillance operations, infiltration and exfiltration missions and beach feasibility studies.

Power

5 The SDV is powered by a lithium-ion battery array. This enables the SDV to be fitted with propulsion, navigation, communication and life-support equipment.

DID YOU KNOW? *The Mark 8 Mod 1 SDV is currently the only SEAL delivery vehicle employed by the US military*

SEAL delivery vehicles

Dive in and explore the submersible used by US Navy SEALs to perform underwater special operations worldwide

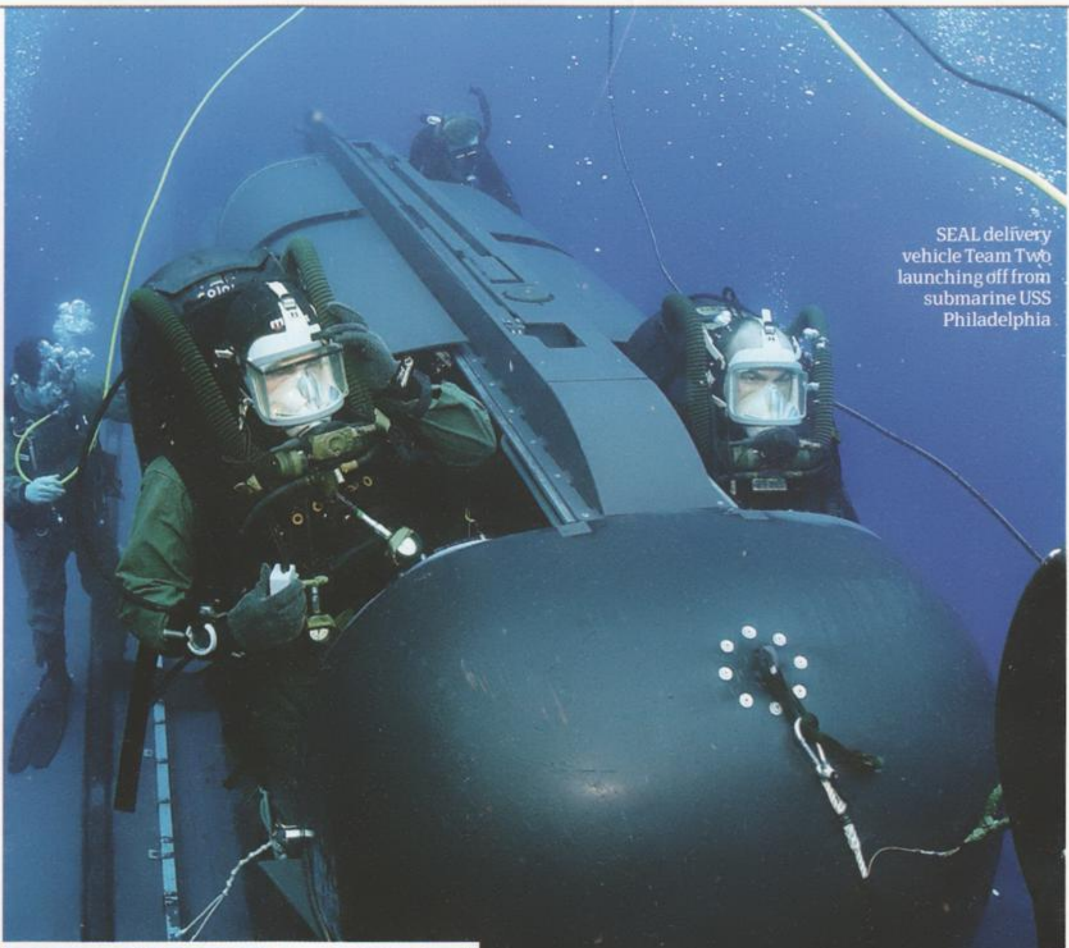
A SEAL delivery vehicle (SDV), as typified by the Mark 8 Mod 1 SDV currently used by US Navy SEALs, is a manned submersible that is designed for a variety of covert special operations. These operations include combat swimmer attacks, reconnaissance and surveillance operations, infiltration and exfiltration missions and beach feasibility studies in war zones all over the planet.

A typical SDV carries a pilot, co-pilot and a combat swimmer team from a dry deck shelter (DDS) – a type of tube-shaped dock that is carried on the back of a nuclear-class submarine – to a maritime mission objective. Importantly, unlike many other submersible craft, the SDV's internal body is flooded, with crewmembers breathing through an in-built oxygen tank array.

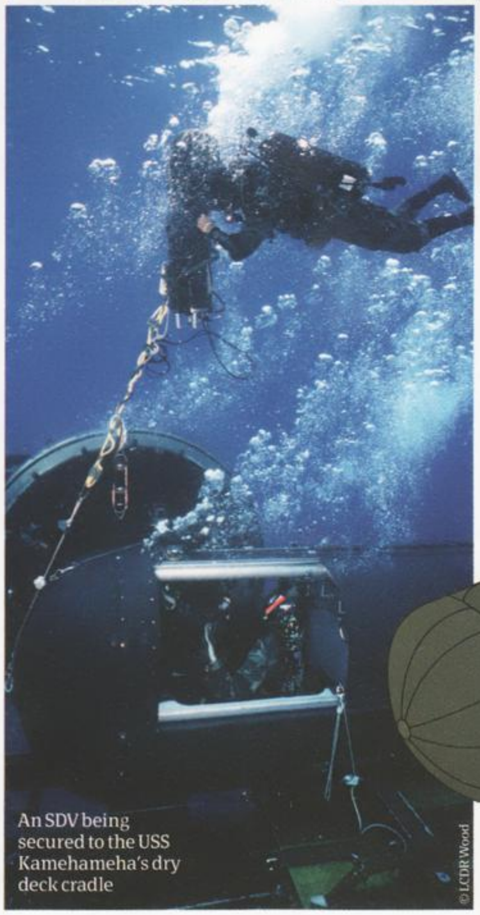
The Mark 8 is powered by a lithium-ion battery stack, equipped with a bladed propeller propulsion unit and navigation suite, and is constructed from a lightweight metal composite. Communication is handled by an ultra-high frequency radio and the internal cabins are accessed by a dual-sliding canopy. Due to its smooth, cylindrical body and minute heat signature, the Mark 8 is very difficult to spot with the use of both sonar or infrared detection systems and is invisible from the surface when at a depth below nine metres (30 feet).

Today, the Mark 8 SDV is used by the US Navy SEALs and Special Boat Service (SBS) of the British Royal Marines.

> *"The SDV's internal body is flooded, with crewmembers breathing through an in-built oxygen tank array"*



SEAL delivery vehicle Team Two launching off from submarine USS Philadelphia

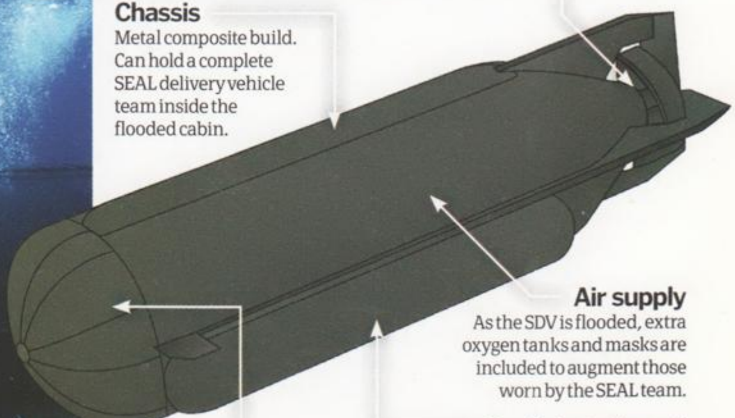


An SDV being secured to the USS Kamehameha's dry deck cradle

© LCDR Wood

MK8 MOD 1 SDV DIAGRAM

We break down the SDV of choice for the US Navy SEALs



Power
The MK8 Mod 1 is powered by a lithium-ion battery array, which can be recharged in-situ.

Chassis
Metal composite build. Can hold a complete SEAL delivery vehicle team inside the flooded cabin.

Air supply
As the SDV is flooded, extra oxygen tanks and masks are included to augment those worn by the SEAL team.

Deck (not shown)
The SDV is transported within a dry deck, which itself is fitted to the top of a nuclear-powered submarine's hull.

Navigation
The Mod 1 is equipped with a suite of navigation sensors as well as a periscope.

> "The biggest advance in recent tractors has been the use of GPS, computers and electronic engine management"

How tractors work

Fitted with air-conditioned cabs, on-board computers and GPS, these workhorses now offer brains and brawn

Tractors can operate a huge range of machinery due to their built-in features such as three-point linkage and power takeoff (PTO). The three-point linkage mounted on the rear of a tractor is used to lift and operate machinery including those that need to function at varying heights/depths, such as ploughs and bulldozer-like scraper blades for mucking out. The three-point linkage comprises two parallel, hydraulically powered lifting arms with the third non-powered arm forming the apex of a triangle. The two lifting arms have hollow ball sockets in their tips that fit over fixed lifting bolts protruding from the item of machinery they are picking up. These are fixed with split pins through holes in the bolts. The third arm acts as a stabiliser and is secured with a nut-and-bolt connection. This triangle configuration is seen in engineering as the strongest way to secure two objects.

Three-point linkage lifting power can vary according to tractor size. Below the three-point linkage is the power takeoff. The PTO is an external drive shaft for powering machinery, and is driven through a clutch from the main gearbox and transmission; it's connected to machinery with a drive shaft via a flexible universal joint. The earliest tractors had a powered flywheel rather than a PTO which worked with a belt drive.

PTOs can power equipment from concrete mixers, pump-operated liquid fertiliser spreaders, auger-operated solid fertiliser spreaders and powered grass cutters. Tractors can also power external hydraulics on machinery such as the hydraulic rams on tipper trailers and larger ploughs, which travel on road wheels and then have to be lowered to operate in a field. A machine's hydraulics system is connected to a tractor through hydraulic hoses (basically tough industrial hose pipes) to connectors on the tractor just above the three-point linkage. The tractor then powers the hydraulics using a specialised pump and fluid reservoir.

The biggest advance in tractors in recent years has been the use of GPS, computers and electronic engine management. Tractor steering can be controlled automatically by GPS, so they plough in straight lines, follow crop rows, or turn to a set pattern keeping the 'headland' (the area at the ends of fields where a tractor turns round) as small as possible. A headland isn't properly cultivated so keeping it as small as possible makes maximum use of the land.

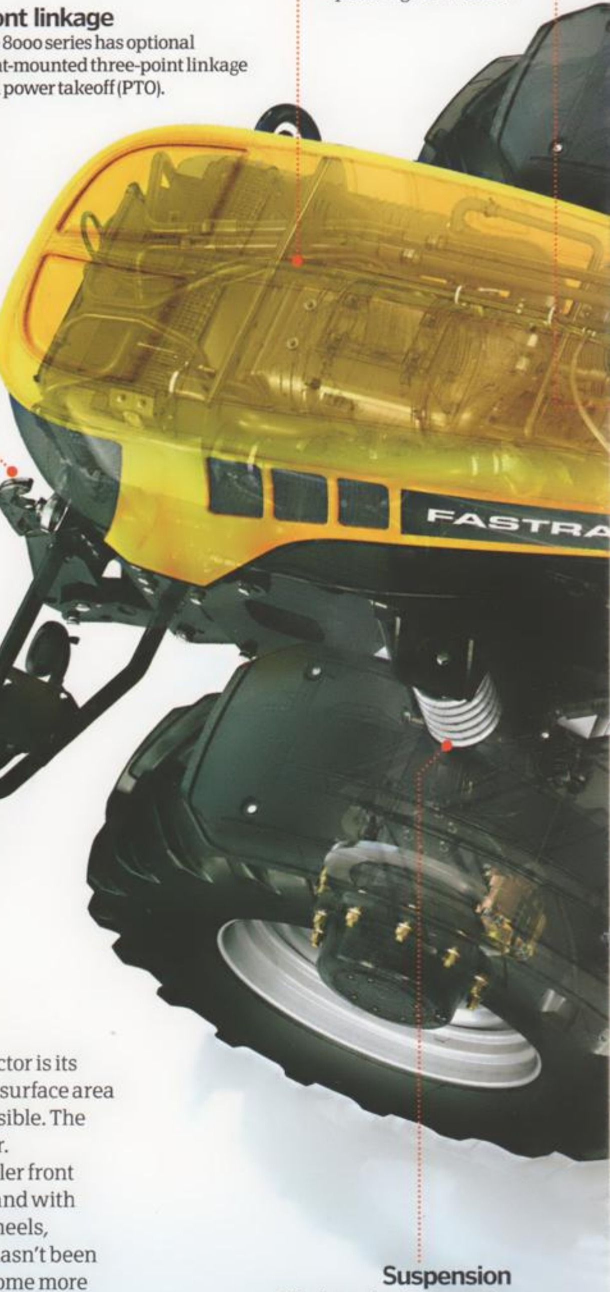
Fields can be electronically mapped using GPS and the soil tested. Once the soil has been analysed, the amount of fertiliser can be adjusted depending on the soil quality in different areas of a field. This information can be stored on a tractor's computer (the most advanced tractors have touchscreen displays in the cabs) or even sent via Wi-Fi to a tractor from the farm office. This electronic mapping has other applications too, such as when planting seeds or calculating the depth at which to operate a plough.

GPS tech is used to ensure the tractor operates at optimum efficiency

All images © JCB

Big wheels

One of the most noticeable features of a tractor is its huge back wheels, which provide as much surface area between the tractor and the ground as possible. The more surface the greater the tractive power. Traditionally tractors have had much smaller front wheels to provide a tighter turning circle, and with two-wheel drive going through the rear wheels, getting traction through the front wheels hasn't been so important. Nowadays tractors have become more specialised. With smaller tractors often two-wheel drive is employed for working in the farmyard, while larger models – known as field tractors – often use four-wheel drive with more equally sized tyres.



Steering
This model comes with power-assisted steering, while a GPS-controlled system ensures the tractor covers every inch of a field, for optimum coverage when spreading fertiliser etc.

Power
8000 series tractors are powered by an 8.5l (2.2-gallon) diesel engine producing up to 310hp and 1,500N torque at 1,400 rpm.

Front linkage
The 8000 series has optional front-mounted three-point linkage and power takeoff (PTO).

Suspension
The four-wheel Fastrac is the only tractor on the market with all-round suspension – one of the factors that enables it to operate at high speed.

5 TOP FACTS
TRACTOR TRIVIA

Biggest

1 Big Bud was a 45-ton, custom-built tractor that had a 3,785 litre (1,000-gallon) fuel tank. With its unique plough, Bud could work 364 hectares (900 acres) in a single day.

Most powerful

2 The US 600hp Case Steiger is the world's most powerful production tractor. The Steiger can come either wheeled or fitted with four individual steered and powered tracks.

Fastest

3 The JCB Fastrac series of tractors (examined in detail below) currently offers the world's fastest production tractors, boasting a top speed of 70km/h (43mph).

Lamborghini

4 Supercar manufacturer Lamborghini started out building tractors. Lamborghini tractors are still made but the tractor company is completely separate from the carmaker.

Hydrogen power

5 Tractor maker New Holland has developed a prototype hydrogen-powered tractor. It's hoped farmers will be able to produce their own renewable energy sources in the near future.

DID YOU KNOW? *Ford manufactured the world's first mass-produced tractor, the Model F, which was launched in 1916*

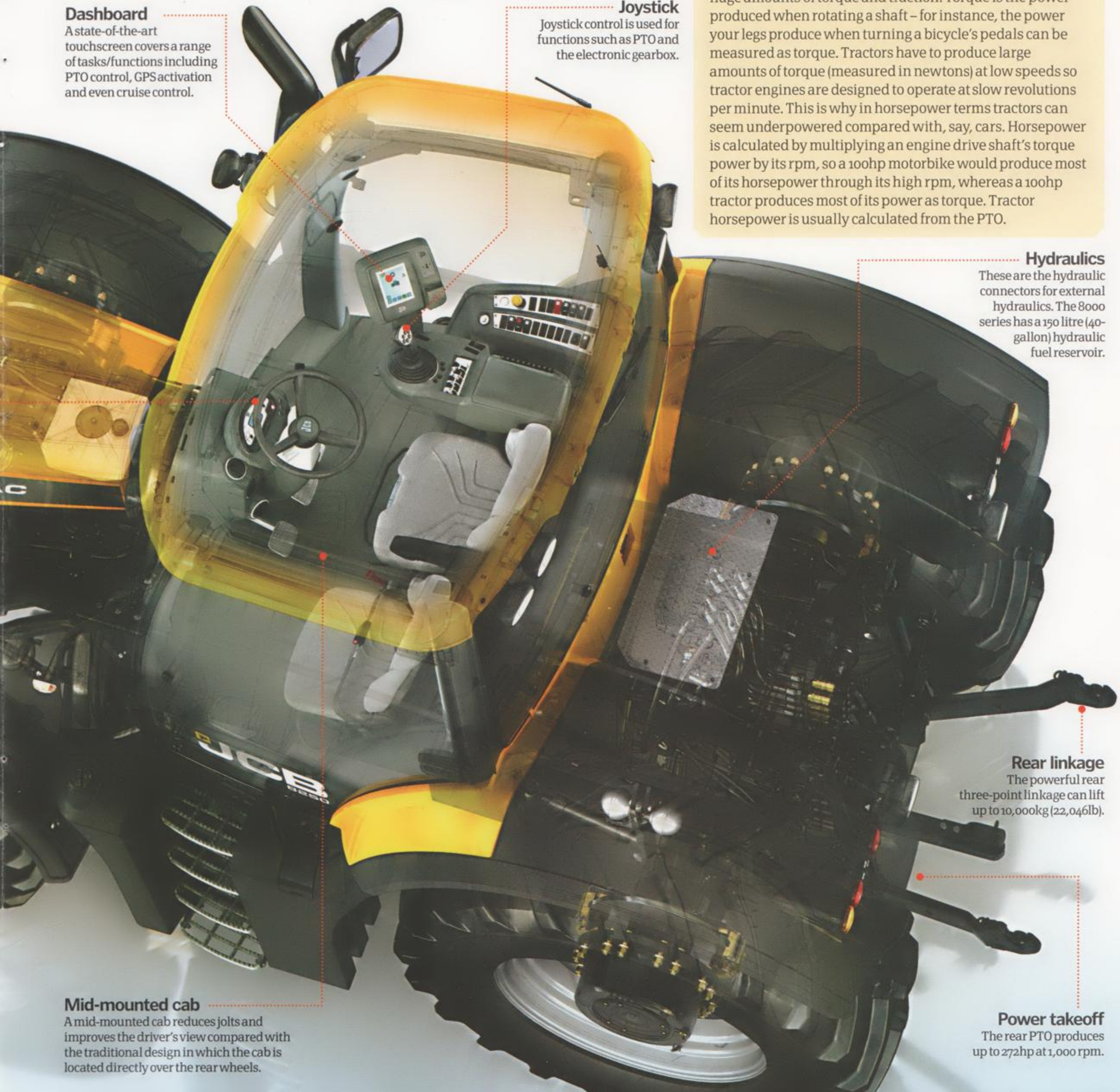
Inside the JCB Fastrac

Launched in 1991 the JCB Fastrac range lives up to its name with a top speed of 70km/h (43mph). JCB tractors are four-wheel drive and the latest version of the 8000 series has a three-mode electronic gearbox and GPS autosteer

Taking the strain

The amazing pulling power of tractors

For all their modern advances tractors would be useless if they couldn't carry out their primary function of moving heavy loads over rough ground. To do this tractors produce huge amounts of torque and traction. Torque is the power produced when rotating a shaft – for instance, the power your legs produce when turning a bicycle's pedals can be measured as torque. Tractors have to produce large amounts of torque (measured in newtons) at low speeds so tractor engines are designed to operate at slow revolutions per minute. This is why in horsepower terms tractors can seem underpowered compared with, say, cars. Horsepower is calculated by multiplying an engine drive shaft's torque power by its rpm, so a 100hp motorbike would produce most of its horsepower through its high rpm, whereas a 100hp tractor produces most of its power as torque. Tractor horsepower is usually calculated from the PTO.



Dashboard
A state-of-the-art touchscreen covers a range of tasks/functions including PTO control, GPS activation and even cruise control.

Joystick
Joystick control is used for functions such as PTO and the electronic gearbox.

Hydraulics
These are the hydraulic connectors for external hydraulics. The 8000 series has a 150 litre (40-gallon) hydraulic fuel reservoir.

Rear linkage
The powerful rear three-point linkage can lift up to 10,000kg (22,046lb).

Mid-mounted cab
A mid-mounted cab reduces jolts and improves the driver's view compared with the traditional design in which the cab is located directly over the rear wheels.

Power takeoff
The rear PTO produces up to 272hp at 1,000 rpm.

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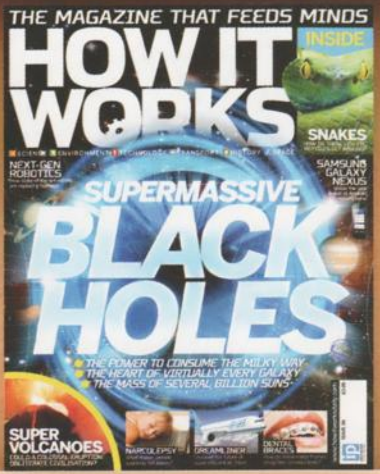
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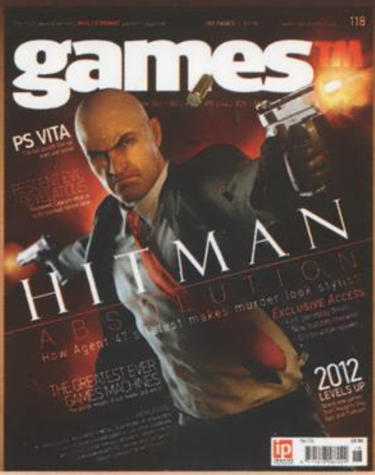
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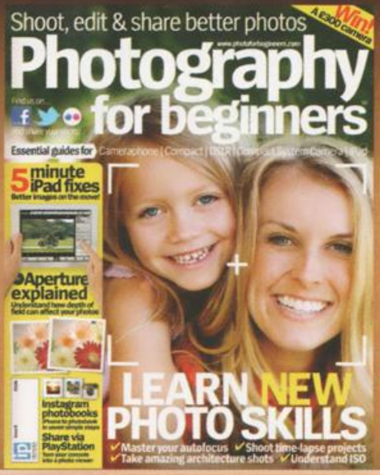
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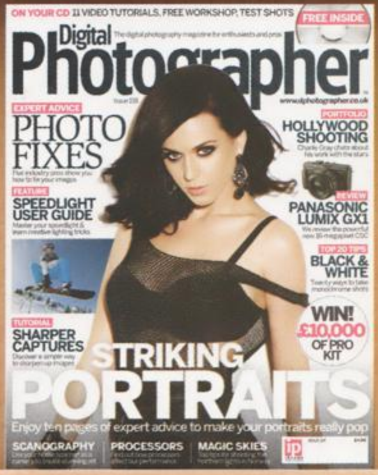
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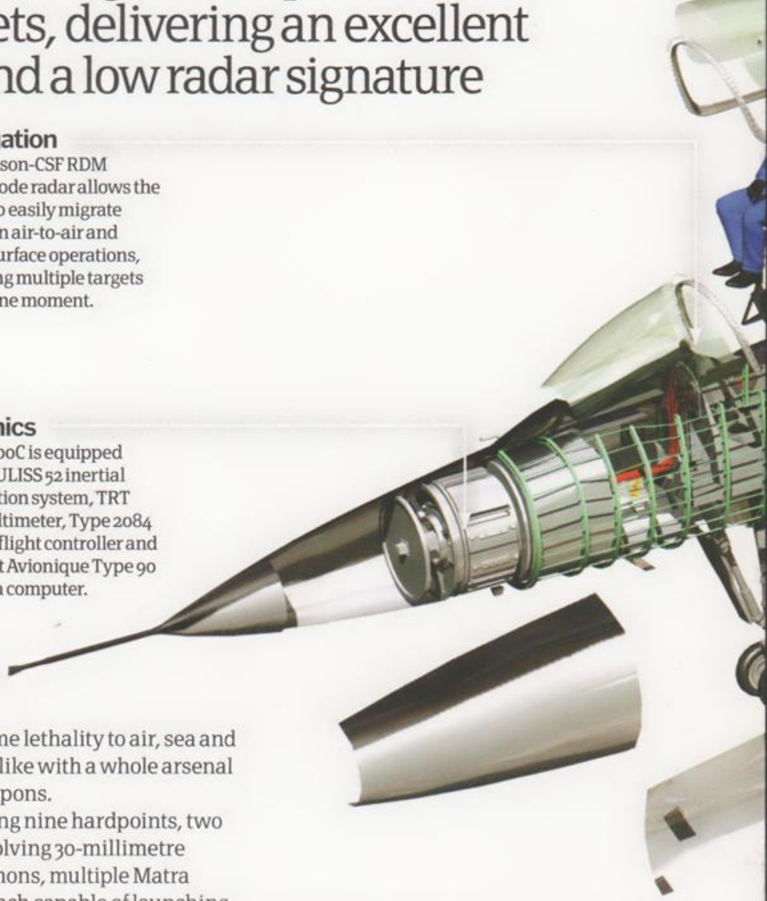
Dassault Mira

A lightweight aircraft boasting diverse multi-role functionality, the Dassault Mirage 2000 epitomises fourth-generation fighter jets, delivering an excellent high-speed flight profile and a low radar signature

Two Mirage 2000Cs during a Baltic air policing deployment role

© Arz



Navigation
A Thomson-CSF RDM multimode radar allows the 2000C to easily migrate between air-to-air and air-to-surface operations, engaging multiple targets at any one moment.

Avionics
The 2000C is equipped with a ULISS 52 inertial navigation system, TRT radio altimeter, Type 2084 digital flight controller and Sextant Avionique Type 90 air data computer.

Despite being overshadowed by more glamorous aircraft over the last 30 years, the Dassault Mirage 2000 series of multi-role fighter jets has quietly delivered excellent functionality and cost efficiency for its operators, which as of 2012, includes nations from Europe, through the Middle East and on to Asia. Of course, it is not all über-hyped eco-credentials and safety features that have heightened and maintained the Mirage's popularity among air forces worldwide – but primarily its ability to deliver extreme lethality to air, sea and land targets alike with a whole arsenal of deadly weapons.

We're talking nine hardpoints, two powerful revolving 30-millimetre (1.2-inch) cannons, multiple Matra rocket pods each capable of launching 18 68-millimetre (2.7-inch) unguided rockets, two R550 Magic short-range air-to-air missiles, two Super 530 medium-range air-to-air missiles, two Exocet AM-39 anti-ship missiles, two AS-30L, laser-guided air-to-ground missiles and the motherload… the ability to deliver a single ASMP tactical nuclear cruise missile into the heart of any region within a 300-kilometre (186-mile) range. As mentioned, when you have this vastness and flexibility of payload on offer, maintenance becomes less of an issue, as let a 2000-series out of the hangar and soon there are no targets left to hit.

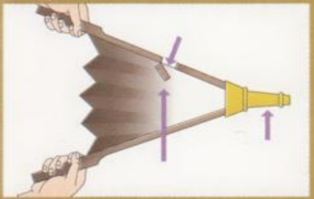
Complementing this insane level of firepower are equally mind-boggling performance characteristics, something granted by the collaboration of a slick delta-wing planform and explosive SNECMA M53-P2 afterburning turbofan powerplant. The M53-P2 enables the Mirage 2000 to hit a top speed of 2,400 kilometres (1,500 miles) per hour and allows it to climb to an altitude of 16,154 metres (53,000 feet) in a minute. The engine's power – which produces on afterburner a maximum of 98 kilonewtons (22,000 pounds force) of

A Mirage 2000B variant pre-takeoff. The jet can climb 16,154m (53,000ft) in 60 seconds

ARMEE DE L'AIR
EQ

This month in History

In the last 30 years advances in fighter jet technology have been huge. Take a look inside the Dassault Mirage, perhaps an unsung hero of the aviation world, and find out what has made it so popular with air forces across the globe. Also up this issue is an insight to the first recorded sound on film with an explanation of the Vitaphone system used in early talkies. Discover the history of Roman villas and how their intricate mosaics were created in ancient times. Then you can take a look at how bellows, water clocks and iron lungs worked too.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HISTORY

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5 TOP FACTS
THE MIGHTY MIRAGE

Nuclear

1 The Mirage 2000 can carry and launch an ASMP nuclear cruise missile. This is a supersonic stand-off missile powered by a liquid-fuel ramjet. It has a max range of 300km (186mi).

Varied

2 The Mirage 2000 is currently operated in many countries worldwide, ranging from its origin country, France, to nations the other side of the planet like Brazil and India.

Marcel

3 The Mirage's manufacturer, Dassault Aviation, was founded by Marcel Dassault in 1930. The company is now the foremost aerial defence contractor in France.

Zippy

4 The design phase of the Mirage 2000 project was incredibly swift, with the jet going from concept, through prototyping to production in just seven years (1975-1982).

Libya

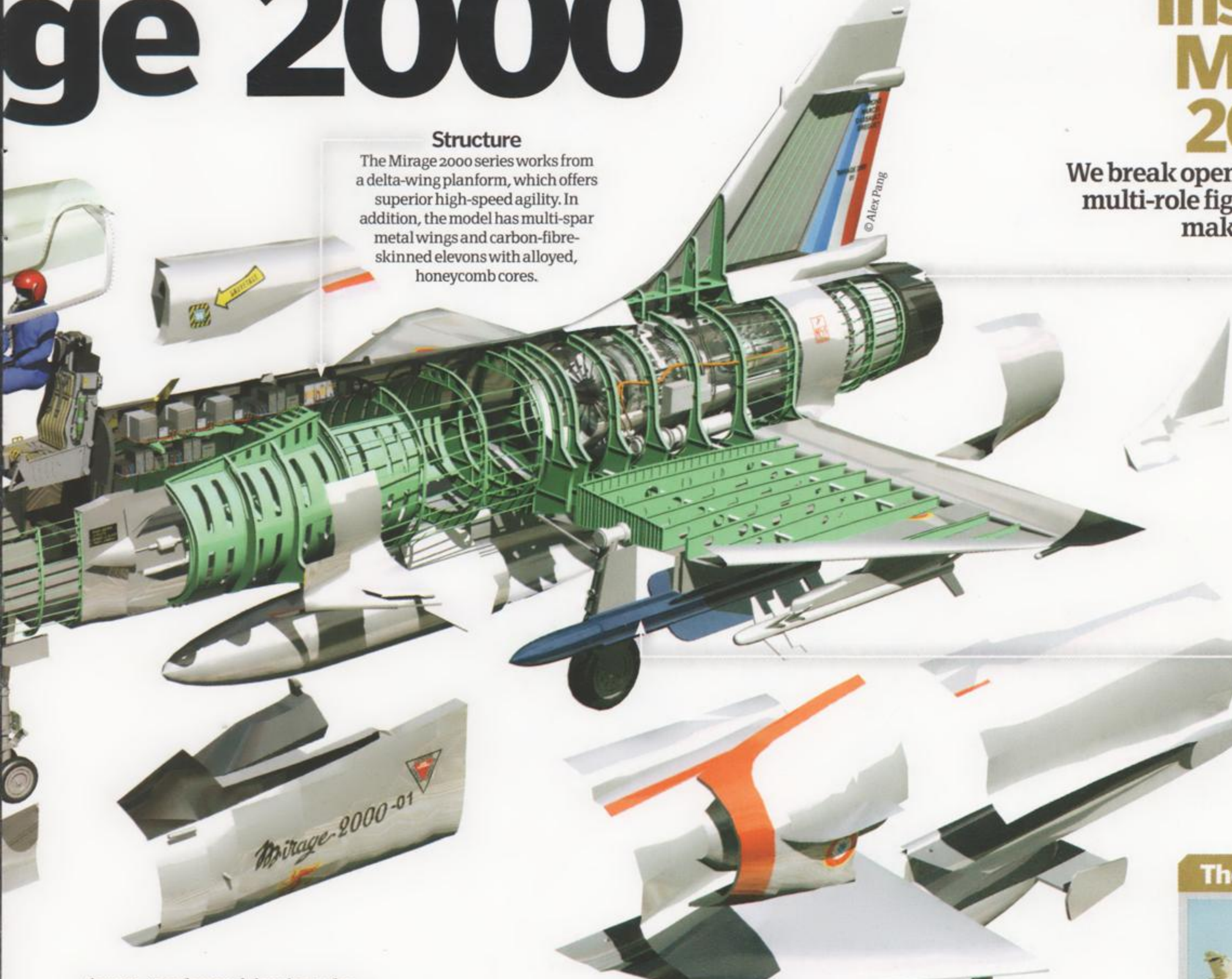
5 Despite being introduced almost 30 years ago, the Mirage 2000 is still in active service. Most recently, French Mirage 2000s helped enforce the Libyan no-fly zone in 2011.

DID YOU KNOW? *Dassault Mirage 2000s featured prominently in the 2005 film Sky Fighters*

ge 2000

Inside a Mirage 2000C

We break open this celebrated multi-role fighter to see what makes it so versatile



©Alex Pang

Structure
The Mirage 2000 series works from a delta-wing planform, which offers superior high-speed agility. In addition, the model has multi-spar metal wings and carbon-fibre-skinned elevons with alloyed, honeycomb cores.

Powerplant
The Mirage's SNECMA M53 turbofan engine can produce a dry thrust of 64kN (14,388lbf) and a whopping 98kN (22,000lbf) in afterburner. The top speed rests at 2,400km/h (1,500mph).

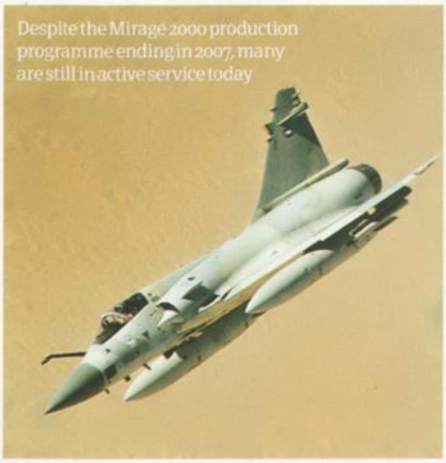
Armament
Aside from two 30mm (1.2in) revolver-type cannons, the 2000C can be fitted with a variety of missiles and bombs over its nine hardpoints. These range from Matra Magic-IIs through to a nuclear cruise missile.

thrust – is enhanced thanks to the 2000's adjustable half-cone air intakes, which provide inclined shocks of air pressure for an incredibly efficient air intake at high speeds.

And it is at these high speeds that the Mirage 2000's delta-wing planform comes into its own, delivering snake-like agility and fluidity of movement. This works because the triangular rearward sweep angle of the jet's wings vastly lowers the airspeed normal to their leading edges, while ensuring the over-wing speed remains less than the speed of sound. This, combined with their inherent large surface area, grants huge lift and minimal wing per unit loading and, as such, super-high airframe manoeuvrability.

This agility is further enhanced by the Mirage being designed with an offset neutral point, which is pushed further forward than its centre of gravity. This makes the aircraft fundamentally unstable during flight, which enables the pilot to make tighter, physics-bending moves.

Indeed, the double-whammy of awesome performance and potential to deal massive damage when cleared for takeoff is ensuring that, despite the Mirage production programme ceasing five years ago, the jet is still being actively used today, representing countries at both home and abroad. A good example of this continued respect for the aircraft's abilities can be seen in France's recent deployment of Mirage 2000s in the enforcement of the no-fly zone in Libya in 2011.


Despite the Mirage 2000 production programme ending in 2007, many are still in active service today

The statistics...

Dassault Mirage 2000C

Crew: 1

Length: 14m (47ft)

Wingspan: 9m (29ft)

Height: 5m (17ft)

Powerplant: 1 x SNECMA M53-P2 turbofan (64kN/14,388lbf)

Max speed: Mach 2.2 (2,400km/h; 1,500mph)

Max range: 1,550km (963mi)

Max altitude: 17,060m (59,000ft)

Armament: 2 x 30mm cannons, 2 x 68mm Matra rocket pods, 2 x Matra R550 Magic-IIs, 2 x AM-39 Exocets, 2 x AS-30L laser-guided missiles, 1 x ASMP tactical nuclear cruise missile, 9 x Mk 82 free-fall bombs

> "In the Fifties, iron lungs were used predominantly for polio patients"

What were water clocks?

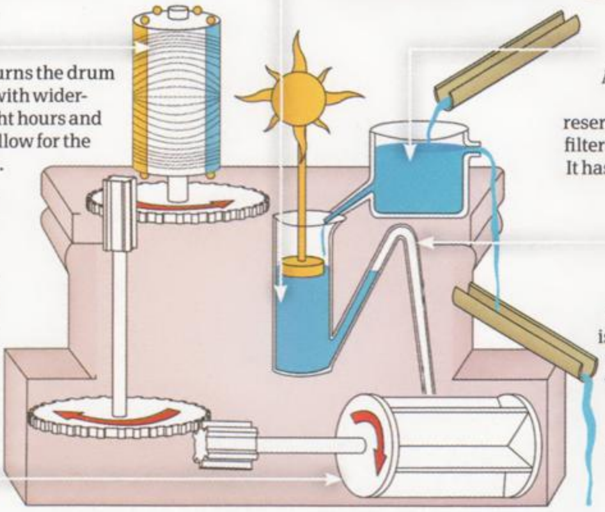
A look at this ancient method of keeping track of the time

The invention of the water clock in 1500 BCE meant that you no longer had to watch the movement of the Sun and stars to tell the time.

The earliest water clocks consisted of a stone vessel, which had a hole at the bottom that allowed water to drip out at a constant rate. The inside of the vessel was marked with a vertical scale to mark the hours, so you were able to read the time according to where the water level was in relation to the scale.

In 250 BCE, Greek inventors made more elaborate water clocks, which they christened clepsydra (translated as thief of water). These incorporated gear systems, dials and pointers. Water clocks remained a major form of public time keeping right up to the 14th century.

What went on inside a clepsydra?



2. Float tank
As this tank fills, it causes the float attached to the hour pointer to move upwards; as it does so it indicates the hour on the drum dial.

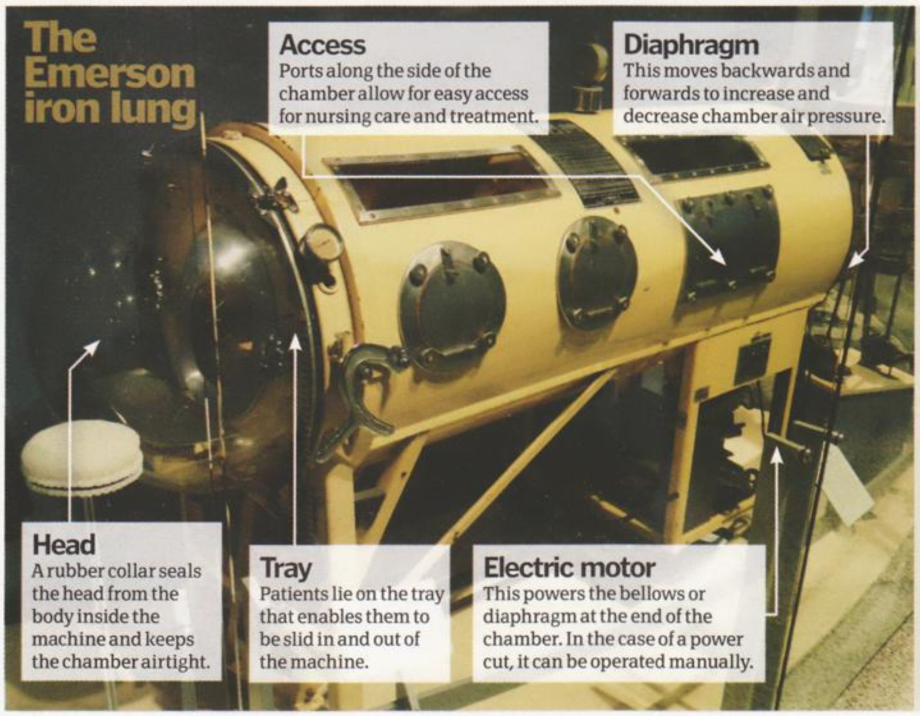
5. Drum dial
The gear mechanism turns the drum dial, which is marked with wider-spaced summer daylight hours and winter night hours to allow for the changes in the seasons.

4. Water wheel
The water released from the float tank siphon turns the water wheel, which through a series of gear wheels turns the drum dial once every 24 hours.

1. Water flow
A constant supply of water is fed to the reservoir, which steadily filters into the float tank. It has a runoff for excess.

3. Siphon
When the hour pointer reaches midnight the water is discharged via the siphon to the water wheel, and the float falls back to the bottom of the tank to start a new cycle.

The Emerson iron lung



Access
Ports along the side of the chamber allow for easy access for nursing care and treatment.

Diaphragm
This moves backwards and forwards to increase and decrease chamber air pressure.

Head
A rubber collar seals the head from the body inside the machine and keeps the chamber airtight.

Tray
Patients lie on the tray that enables them to be slid in and out of the machine.

Electric motor
This powers the bellows or diaphragm at the end of the chamber. In the case of a power cut, it can be operated manually.

How does an iron lung work?

The life-saving negative-pressure ventilator explained

Philip Drinker and Louis Agassiz Shaw developed the first viable iron lung machine in 1927. Their prototype comprised a large iron box and two vacuum cleaners. However, John Emerson invented a cheaper and more refined iron lung machine in 1931.

The machine consisted of a steel cylinder or box that encased the patient's body, except for their head. An electrically operated pump increases and decreases the air pressure inside the airtight chamber, which causes the patient's lungs to inflate and deflate to reproduce a normal breathing pattern. When the air pressure is at its lowest, the lungs expand and allow air to be inhaled. When the air pressure is increased, the chest and lungs are compressed, causing the air to be exhaled.

In the Fifties, iron lungs were used predominantly for polio patients. Since then positive-pressure ventilators that send air directly into the lungs have superseded iron lung machines.

Fire bellows explained

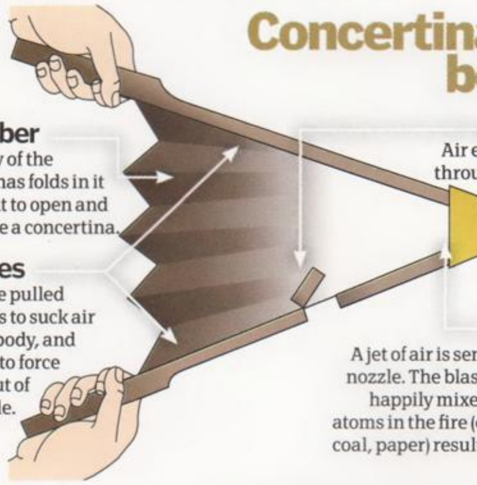
Discover the simple but super-useful tool that can help bring a fire back to life

A set of bellows consists of a collapsible folding chamber that can be opened and closed. In the process of opening the chamber, it takes in air and, on closing, it expels a jet of pressurised air.

The simplest bellows are opened and closed by a set of handles on either side of the air chamber; by moving them inwards and outwards air can be rapidly collected and then sent out through the nozzle. The most common purpose of bellows was to supply oxygen to feed a domestic fireplace, either to get it started or to encourage dying embers to rekindle.

In ancient times, bellows were also essential to increase and maintain the high temperature of furnaces, and blacksmiths used double-chamber bellows to keep their forges hot.

Concertina-type bellows



Chamber
The body of the bellows has folds in it to allow it to open and close, like a concertina.

Handles
These are pulled outwards to suck air into the body, and inwards to force the air out of the nozzle.

Side valve
Air enters the bellows through a valve or flap.

Nozzle
A jet of air is sent out through the nozzle. The blast of oxygen atoms happily mixes with the carbon atoms in the fire (eg burning wood, coal, paper) resulting in more heat.

5 TOP FACTS EARLY CINEMA

Celluloid

1 In 1889, Eastman Kodak introduced celluloid, a transparent flexible film with a photosensitive emulsion. Reels of celluloid were essential for the creation of movies.

The cinematograph

2 Louis and Auguste Lumière patented their cinematograph apparatus in 1895. In the same year, they used it to show films to a paying audience at Le Grand Café in Paris.

Special effects

3 In 1896, showman Georges Méliès used the Theatre Robert-Houdin as the first public cinema. He played with special effects to make several fantasy and sci-fi films.

The Great Train Robbery

4 This 12-minute film, directed by Edwin Porter, used location shooting, camera movement, closeups, cross cutting, double exposures and editing to throw the viewer into the action.

The Birth Of A Nation

5 This DW Griffith film was an epic three-hour depiction of the US Civil War. It had an orchestral accompaniment, which added to its huge success. It was a forerunner of the 'blockbuster'.

DID YOU KNOW? When Al Jolson prophetically said, "You ain't heard nothing yet," in The Jazz Singer, audiences stood and cheered

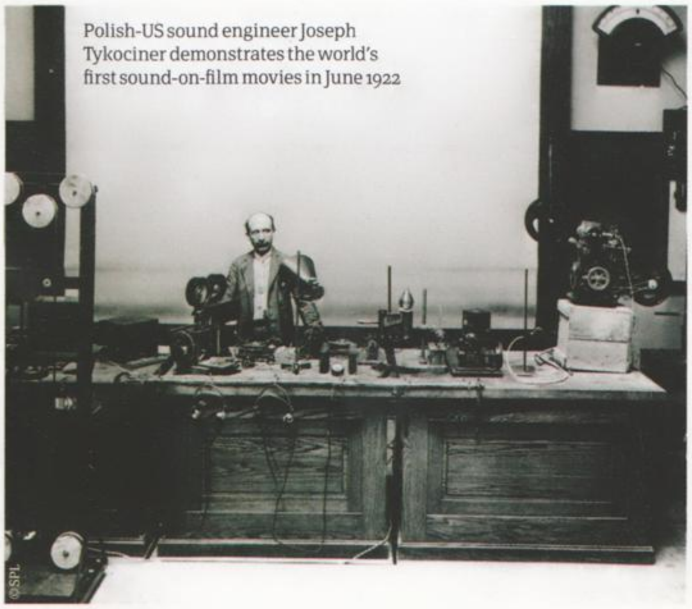
First talking pictures

Discover the history of the technological race to introduce sound to the cinema

It took over 40 years for synchronised sound systems to be successfully introduced to cinemas, bringing audio to the movies. There were two major approaches to synchronising sound with films. One was to use gramophone discs to record and play back the sound, as demonstrated in the Vitaphone system (see below), while the other approach was to install the sound on an optical track alongside the images on the film itself.

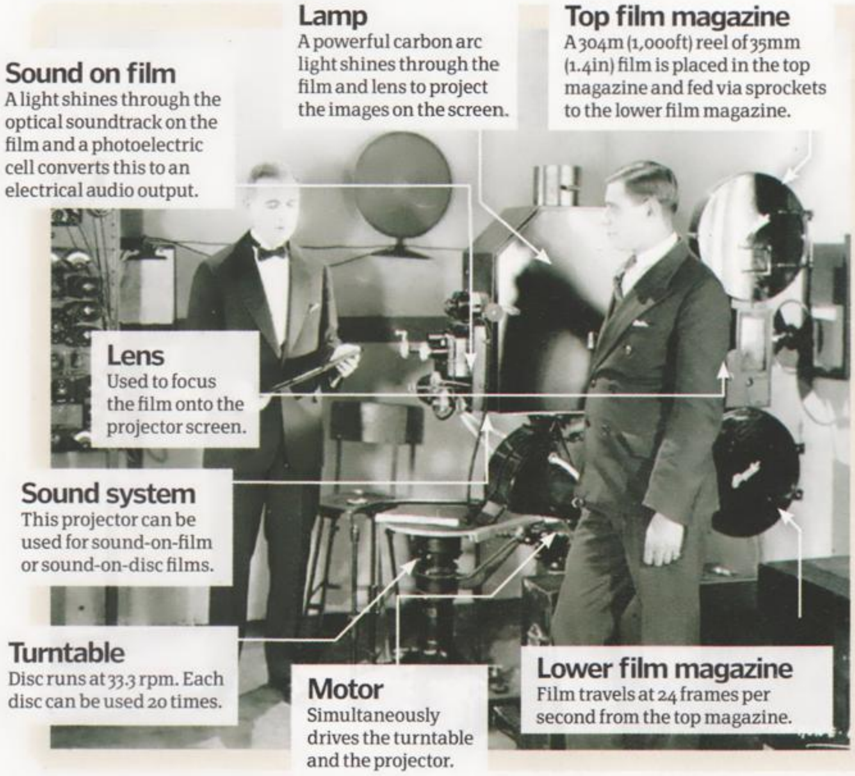
Sound-on-film evolved through a series of inventions. One significant patent in 1919 was for Tri-Ergon's variable density technology. This employed a flywheel mechanism that fed the film through the projector sprockets at a constant speed to prevent the sound on the film being distorted. Second, they used a photoelectric cell to convert electrical waves into light waves that could be recorded onto the edge of the film reel. The projector contained a photoelectric cell that converted the light waves back into electrical waves that were then amplified and played to the cinema audience.

At the same time Lee De Forest produced a similar Phonofilm system; however, to make it viable he had to use a gas-filled AEO light tube which, in response to an audio input, produced light waves that could be photographed. Theodore Case, the inventor of the AEO light, with his assistant Earl Sponable, developed this technology at the Case Research Laboratory to produce the Movietone system for the Fox Film Corporation. It was used to make Movietone News newsreels from between 1928 and 1939, and feature films until 1931.


Polish-US sound engineer Joseph Tykociner demonstrates the world's first sound-on-film movies in June 1922

©SPL

> "The projector contained a photoelectric cell that converted the light waves into electrical waves that were then amplified and played to the audience"


Sound on film
A light shines through the optical soundtrack on the film and a photoelectric cell converts this to an electrical audio output.

Lamp
A powerful carbon arc light shines through the film and lens to project the images on the screen.

Top film magazine
A 304m (1,000ft) reel of 35mm (1.4in) film is placed in the top magazine and fed via sprockets to the lower film magazine.

Lens
Used to focus the film onto the projector screen.

Sound system
This projector can be used for sound-on-film or sound-on-disc films.

Turntable
Disc runs at 33.3 rpm. Each disc can be used 20 times.

Motor
Simultaneously drives the turntable and the projector.

Lower film magazine
Film travels at 24 frames per second from the top magazine.

The Vitaphone system

Bell Laboratories and Western Electric, for the Warner Bros film studio, created the Vitaphone sound-on-disc system.

To stop the noise of its motor being picked up by the microphones positioned over or in the film set, the Vitaphone camera was housed in a soundproof booth. The sound was sent to a monitoring room where a technician balanced the sound levels before it was amplified and recorded on a wax disc.

The Vitaphone projector motor also drove a gramophone turntable. The projectionist cued a 'start' frame on the film and dropped the stylus on a marked groove on the 400-millimetre (16-inch)-diameter shellac disc. The projector motor was switched on, and the film and turntable simultaneously reached the proper running speed. Each disc ran for ten minutes corresponding with the running time of one reel of 35-millimetre (1.4-inch) film.

CINEMA SOUND TIMELINE

1888
Phonograph
Thomas Edison experiments with matching moving pictures with his phonograph sound system.

1895
Kinetoscope
William Dickson makes the Kinetoscope peepshow machine, which matches a short film with phonographic sound via headphones.

1913
Kinetophone
A long pulley linked to a 140mm phonograph cylinder with a film projector to synchronise the sound with the images.

1919
Sound on film
Lee De Forest produces Phonofilm, which records the synchronised soundtrack on the film itself rather than a separate disc.

$10,000 REWARD
The De Forest Phonofilms
Weber & Fields
Eddie Cantor
Ben Bernie's Orchestra
Buck & White
Sissle & Blake
Eva Leoni
De Wolf Hopper
Conchita

1927
First feature
Warner Bros, using the Vitaphone system, releases *The Jazz Singer* with Al Jolson. It features dialogue and singing.

AL JOLSON
JAZZ SINGER

1928
Hollywood embraces talkies
The major Hollywood studios – Paramount, Loews/MGM, First National and United Artists – all adopt synchronised sound.

> "The Roman villa was not simply a house but a symbol of its owner's power"

Inside a Roman villa

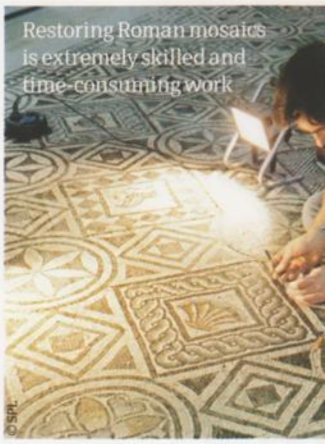
Home and hearth in Ancient Rome explained

Roman villas were magnificent structures built using stone, wood and brick. The walls were made from opus caementicium (Roman cement) that were later faced with stone. The villas' tiled roofs could be both sloping and flat, while the floors were made of concrete. Throughout Roman history the villa adopted many architectural features, which changed over time – however, the villas were always designed around an open courtyard and pool. During the summer it was important that light and air were accessible, while at night, the inner recesses were lit by oil lamps. The villa was divided into several suites; these included rooms for family and guests and an accommodation block for staff and slaves. Around the central villa, there were also animal sheds and granaries.

The Roman villa was not simply a house but a symbol of its owner's power and position within society. Therefore, each upper-class Roman sought to impress and intimidate his associates with the building of fine houses constructed within luxurious settings. Within the city walls there was little space, and the Roman villa tended to be small and compact. For this reason the upper classes often took country residences; these houses were used during the hot summer months and were designed as a dwelling for the family, their slaves and estate workers.

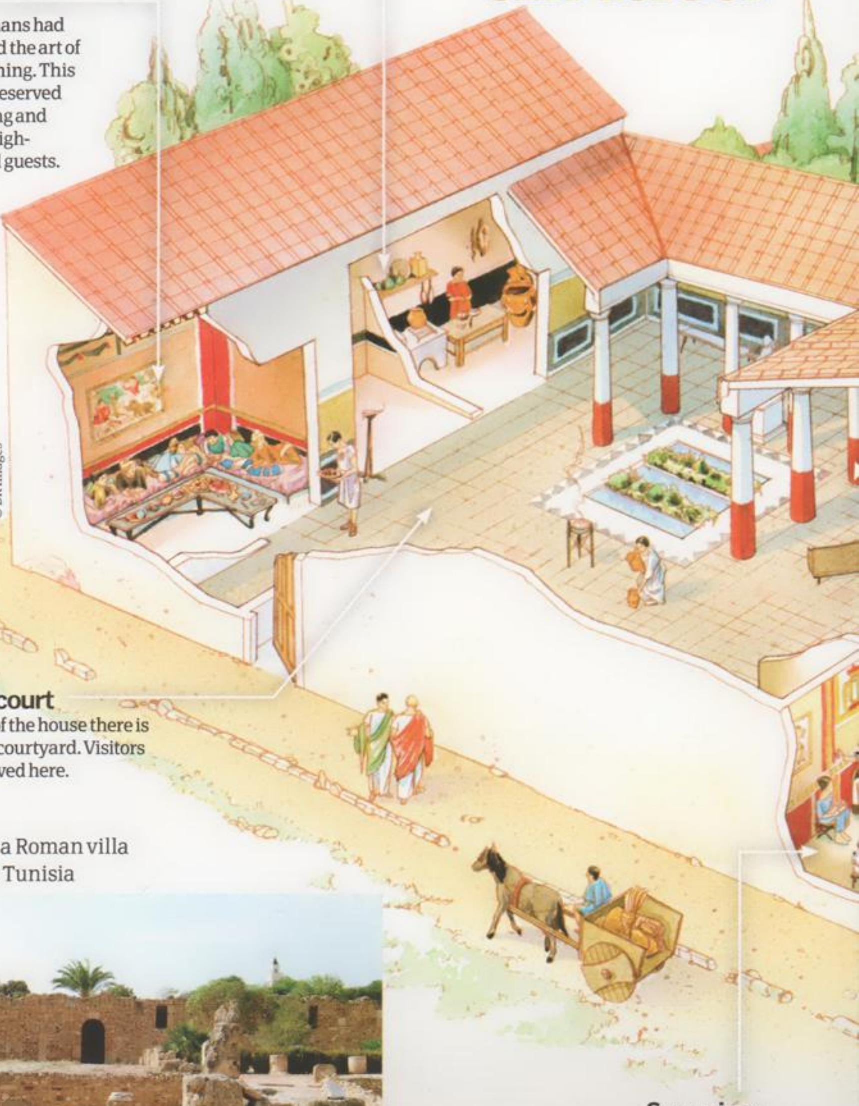
The Romans were also interested in agricultural profiteering, so these country villas had landholdings – known as latifundia – and through them, the Roman elite became largely self-supporting, exploiting grain, olive groves and vineyards. They were proud of their self-sufficiency and were able to cultivate fruit and vegetables, as well as keeping fish farms. The Romans also enjoyed ocean-side villas, which provided healthy sea air and brief periods of relaxation before returning to the stress and congestion of city life.

Villas were very much multifunctional residences. As well as being designed to house offices and meeting rooms, they were also used to entertain important guests. They had reception areas, dining rooms, baths and libraries. Like notable English stately homes, they became dynastic symbols of their era.


Restoring Roman mosaics is extremely skilled and time-consuming work

© SPL

The villa divided


© DK Images

Culina
The kitchen area is manned by slaves and servants. The Romans enjoyed exotic dishes that included stuffed dormice and snails.

Oeci
The Romans had perfected the art of entertaining. This room is reserved for wining and dining high-powered guests.

Open court
In front of the house there is an open courtyard. Visitors are received here.

Sacrarium
This room contains a shrine. It is here that the family worship their household gods.

This villa in Tivoli, Italy, was used as a retreat by Roman emperor Hadrian

The ruins of a Roman villa in Carthage, Tunisia

Head to Head
ROMAN EXCAVATIONS

OLD

© Wknight94

1. Hadrian's Villa, Italy

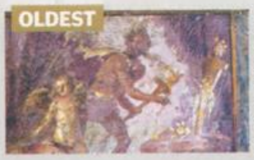
Dating to the 2nd century AD, this villa, in Tivoli, Italy, revealed important features, including vast underground tunnels and an island retreat.

OLDER

2. Aquincum

Located on the outskirts of Budapest, Aquincum was a vital military base circa 89 AD, which developed into one of the Roman Empire's key cities in central Europe.

OLDEST



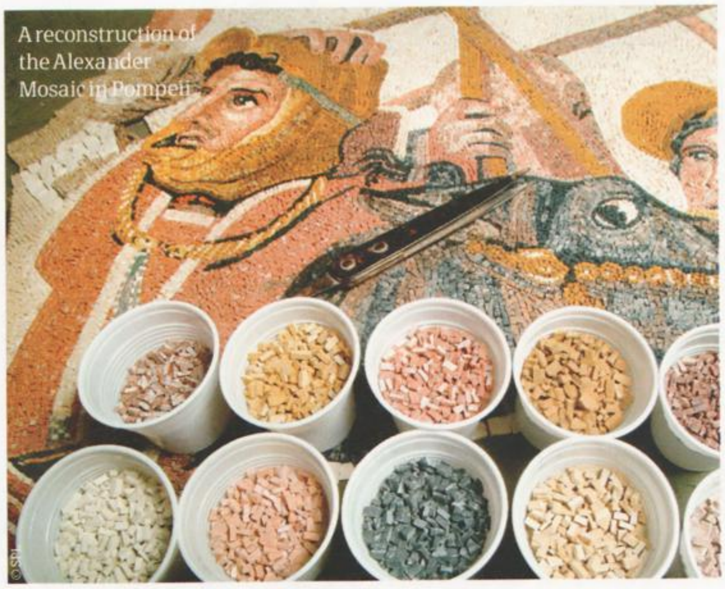
3. Villa of the Mysteries

Dated to 79 AD, this Pompeii villa is known for its frescoes that show the initiation of women into ancient mystery cults.

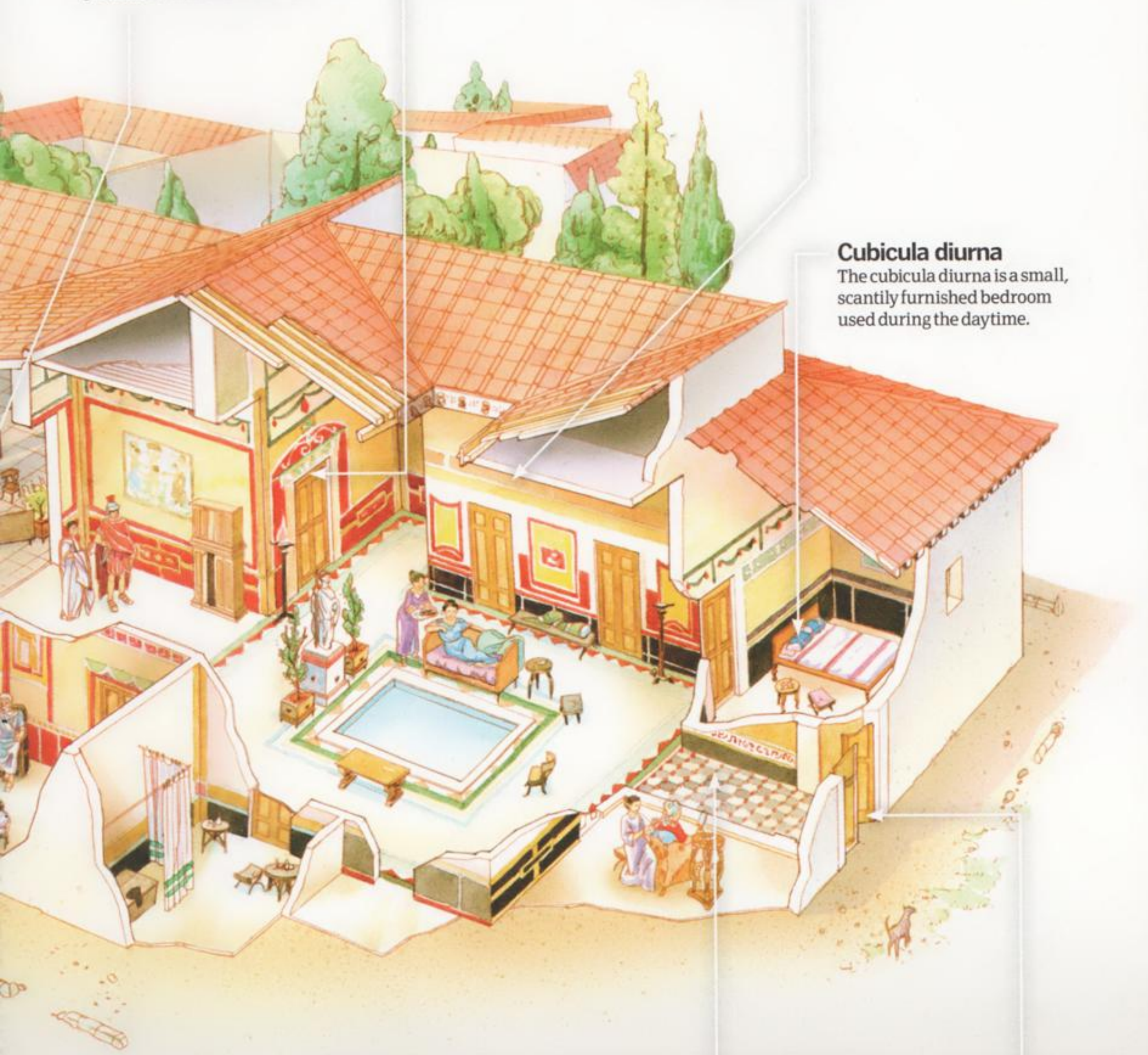
DID YOU KNOW? In western Europe, deserted Roman villas were often reused for medieval burial sites

Making mosaics

Mosaic-making is an ancient art form that was used in eastern traditions long before the birth of the Roman civilisation. However, the Romans perfected the practice using natural materials such as tiles, pebbles and glass. These would be cut into fragments, known as tesserae. They would be placed by a master craftsman on a floor of smooth plaster to create interesting and colourful imagery. The Romans could create vast floors of mosaic that could measure up to ten metres (30 feet) long, often opting for magnificent scenes of wildlife, hunting and gladiatorial contests. From time to time, they also used amusing and even practical images – one villa was designed with a floor of mosaic food; if any morsel were dropped from the table it would go unnoticed.


A reconstruction of the Alexander Mosaic in Pompeii

© SPL



Peristylium
An open courtyard built at the back of the tablinum. The house is designed around a shaded courtyard, which provides relief from the heat.

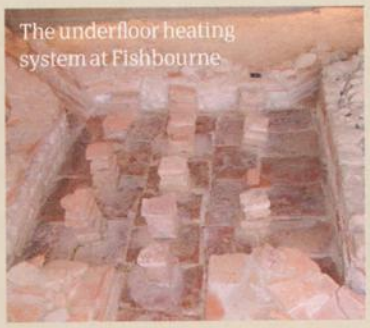
Tablinum
The main office used by the master of the house. He keeps documents, money and valuables here.

Atrium
A large square room, it is designed with an open space in the ceiling. The room often contains the busts of family ancestors.

Cubicula diurna
The cubicula diurna is a small, scantily furnished bedroom used during the daytime.

Vestibulum
From here there is a decorated pavement that stretches from the door to the street.

Ostium
The door is bolted at night and guarded by a doorman.

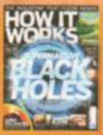

The underfloor heating system at Fishbourne

Fishbourne Roman Palace

Discovered in 1960, Fishbourne Roman Palace, in West Sussex, England, had four wings that were lined with colonnades. It also featured courtyards, halls and a bathhouse equipped with underfloor heating. The Roman palace is thought to have been built on a larger scale than the greatest European palaces. Erected during the 1st century AD, it was embellished with gardens, pools and statues. The house was occupied and extended over several hundred years – each resident improving the dwelling and creating beautiful decorative mosaics, the most famous being the Dolphin mosaic, which is located in the north wing. The house eventually succumbed to fire and was destroyed in 270 AD, after which it was abandoned. There are mixed theories as to the ownership of the villa, but it may have belonged to client kings or Roman leaders – one of whom is thought to be Tiberius Claudius Catuarus whose ring was discovered there.

BRAIN DUMP

Because enquiring minds want to know...



Ask your questions

Send us your questions using one of the methods opposite and we'll get them answered

sciencemuseum www.sciencemuseum.org.uk

HOW IT WORKS EXPERTS

sciencemuseum

Louise Thomas
Science Museum explainer

Louise previously worked as a freelance museum educator. She has an MA in Museum Studies, enjoys spaghetti bolognese and loves to play the not-so-talked-about sport of ten-pin bowling.

Kate Mulcahy
Science Museum explainer

Before working as an explainer Kate was a teacher of maths, English and physics. In her spare time she plays rugby and likes making things such as clothes and cakes.

Rachel Harvey
Science Museum explainer

Rachel is one of the newer explainers at the Science Museum. Before becoming an explainer, she was a physics teacher. She has a worrying love of penguins and also likes discovering new parts of London.

Laura Mead
Science Museum explainer

Laura is a newbie to the explainer team. She has a BSc in Environmental Science and a working background in museums and education. She loves working with the visitors at the Science Museum and inspiring them to be inquisitive about science.

What makes milk turn sour?
Find out on page 84

As large as it is, the visible universe is constantly getting even larger

How big is the universe?

Norm

■ To answer this we can make estimates based on the expected age of the universe and the motion of galaxies. The universe itself is expanding, but not in the way a balloon does. The expansion is taking place throughout the universe, where space-time itself is being stretched outwards. Whereas a balloon pushes its edges out as it expands, the universe is also pushing its insides outwards, but with no centre to the universe, everything is moving away from everything else. It's a bit like baking a ball of dough; the entire dough grows, not just its edges. However, based on our knowledge of how old the universe is – roughly 14 billion years – we can observe a theoretical 'edge' of the visible universe about 14 billion light years away from us. This is the furthest distance we can see, as light that might be further has not had time to reach us yet. Thus, we can say that the visible universe has a diameter of 28 billion light years, 14 billion light years in either direction from Earth. However, what's beyond this is unknown. The visible universe we can observe could be just a tiny fraction of a much larger universe, or perhaps just one in a system.

HIW

© NASA, ESA

Can energy be destroyed?

Naseem

The law of conservation of energy states that energy cannot be created nor destroyed, only transferred from one form to another. Energy can exist in different forms, such as thermal (heat), kinetic (movement) and potential (stored). Not all energy is transferred to 'useful' forms of energy though – for example, when you run, some of the chemical potential energy you use (from food) is 'lost' as heat and sound. According to some scientists, all energy and mass were created when the universe was born in the Big Bang nearly 14 billion years ago, and energy can be converted into mass (and vice versa).

Rachel Harvey

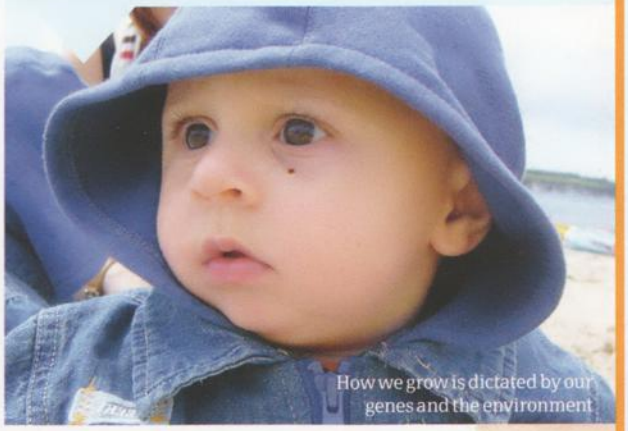
Energy is pretty tough – in fact, it's thought to be indestructible!

Why do we stop growing?

Keith Graves

We stop growing because we are genetically programmed to. Our genes, from our parents, determine how we develop but environmental factors also affect how tall we grow. We know our DNA controls the growing process, but scientists are still unsure how our genes do this. We stop growing when we reach the age at which our bodies can reproduce. At this point, the purpose for growth is complete so our genetic control centre tells us to stop.

Louise Thomas



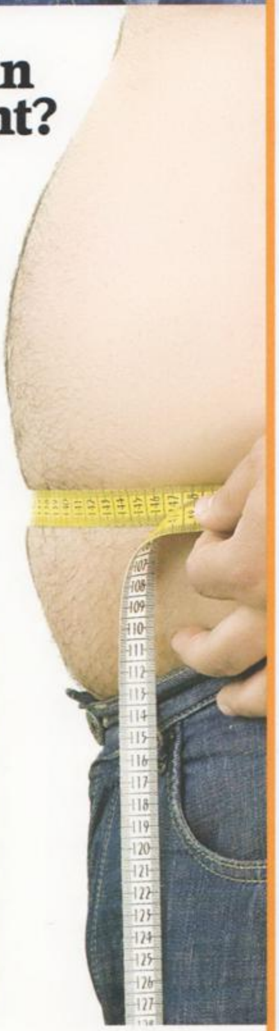
How we grow is dictated by our genes and the environment

Why do we gain and lose weight?

Paul Whitting

Humans use the energy in food to live; this energy is measured in calories. If people consume lots of calories from food and don't burn them up, they get converted to fat and stored in the body and so people gain weight. This was very important when humans were not always guaranteed access to food daily. They could use the stored fat in their bodies for energy until they could find food again. If people burn more calories than they consume through food, by doing lots of exercise etc, then their bodies use the fat stores instead and, as a result, they lose weight.

Kate Mulcahy



How quickly does human hair grow?

Phillip House

Human hair grows on average 1.25 centimetres (0.5 inches) per month, which is equivalent to about 15 centimetres (six inches) per year. There are several variables that can affect hair's growth rate such as age, health and genetics. Each hair grows in three stages, the first being the anagen phase where most growth occurs. The longer your hair remains in this stage dictates how long and quickly it develops; this can last between two and eight years and is followed by the catagen (transitional) and telogen (resting) phases. Hair growth rates vary across different areas of the head, with that on the crown growing the fastest.

Laura Mead

sciencemuseum

What's on?

Hidden Heroes

WHAT: Could you be bothered to brew leaf tea five times a day or fish the beans out of your morning coffee? Hidden Heroes shines the spotlight on the overlooked inventions we couldn't live without. The inventions are presented alongside original sketches and drawings by their inventors, patent specifications and original adverts. The exhibition reveals the efforts made to establish each product, as well as sharing quirky titbits of information.

WHERE: First floor

WHEN: Until 5 June 2012

PRICE: Adults: £6, Concessions: £3.50, Family: £16

Electroboutique Pop-up

WHAT: Innovative art production company Electroboutique (Russian artists Alexei Shulgin and Aristarkh Chernyshev) create interactive artworks that subtly communicate strong critical attitudes. Encouraging participation through 'creative consumption', the artists generate an original dialogue with their audiences through works which respond, reflect and re-version viewers in real-time.

WHERE: Ground-floor mezzanine

WHEN: Until 14 February 2012

PRICE: Free

Further information

For further information, visit the What's On section at www.sciencemuseum.org.uk.

Visit the Museum

Exhibition Road, South Kensington, London, SW7 2DD. Open 10am-6pm every day. Entry is free, but charges apply for the IMAX 3D cinema, simulators and special exhibitions.

BRAIN DUMP

Because enquiring minds want to know...

When did London buses start to run?

Find out on page 86

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

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HOW IT WORKS EXPERTS

MANCHESTER 1824
The University of Manchester
The Manchester Museum

Kate Sherburn
Curatorial assistant of Natural Sciences at The Manchester Museum

Kate works with the Zoology and Palaeontology collections at the Museum. She is particularly interested in aquatic biology, especially sharks. She travels all over the world to see animals in their natural environment.

Bryan Sitch
Curator of Archaeology at The Manchester Museum

Bryan has been curator of Archaeology at The Manchester Museum for five years. Before he has worked for museums in Hull and Leeds. At the moment he's working on the Ancient Worlds display.

David Gelsthorpe
Curator of Earth Science collections at The Manchester Museum

With a PhD in Palaeontology, David has been a curator at The Manchester Museum for five years. He loves using the collection to show people how amazing the planet is.

Andrea Winn
Curator of Community Exhibitions at The Manchester Museum

Andrea has been working at The Manchester Museum for four years in outreach and engagement. She has a background in social and economic history.

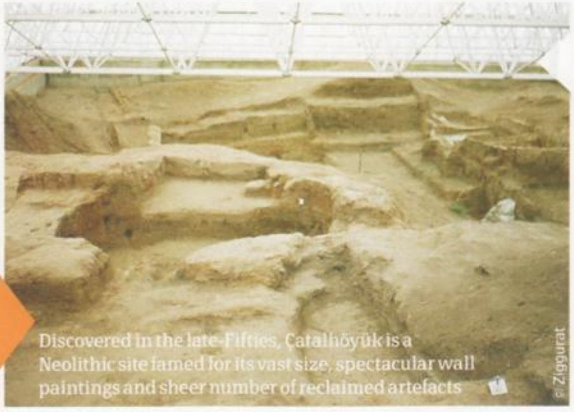
The deepest Tube station in London

On page 87

Why does milk turn sour?

Juliette Williamson

Milk contains a sugar called lactose. It also contains harmless bacteria called lactobacillus, which uses lactose for energy and creates lactic acid as a by-product. It is the lactic acid which makes milk taste sour. Pasteurising milk kills off harmful bacteria and greatly reduces the number of lactobacillus ensuring that milk will last up to three weeks in a fridge. Lactobacillus is a very useful bacterium as the acidic conditions it creates makes a milk protein called casein turn to curd. Without curd we would not have dairy food products like cheese.
Kate Sherburn



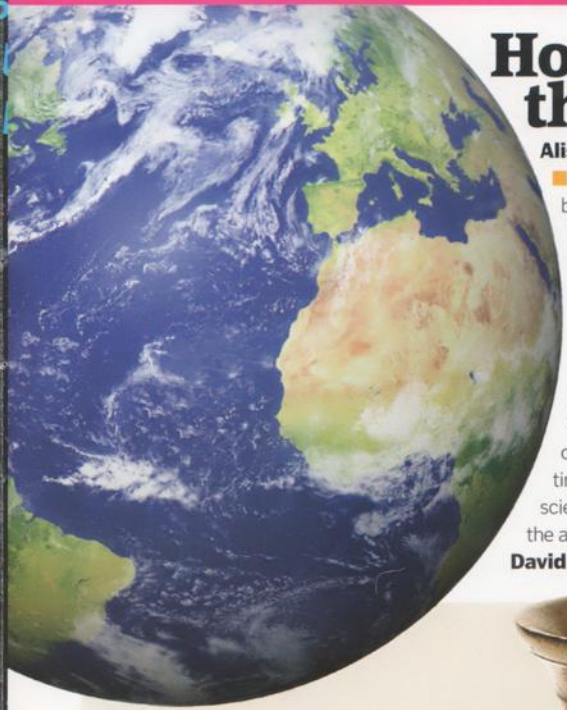
Discovered in the late-Fifties, Çatalhöyük is a Neolithic site famed for its vast size, spectacular wall paintings and sheer number of reclaimed artefacts

© Ziggurat

What's the biggest archaeological site?

Lucy Bailey

The prehistoric site of Çatalhöyük in Turkey covers about 13 hectares (32 acres), while the Palace of Knossos, Crete, covered an area of about 13,000 square metres (140,000 square feet). Pompeii covers an area of 60 hectares (145 acres) and has been described as 'the most complete urban excavation ever undertaken'. This is tiny in comparison to the ruins of the temple complex of Angkor Wat in Cambodia, which may cover up to 3,000 square kilometres (1,160 square miles)!
Bryan Sitch



How old is the Earth?

Alistair Roberts

Our home planet is about 4.5 billion (4,500 million) years old. This date is based on samples from the Earth, meteorites and the moon, which all come from when the Earth first formed. Scientists have looked at radioactive chemicals in the rocks which react into new chemicals over a certain period of time. By working out how many times this reaction has taken place, scientists are then able to determine the age of the rock.

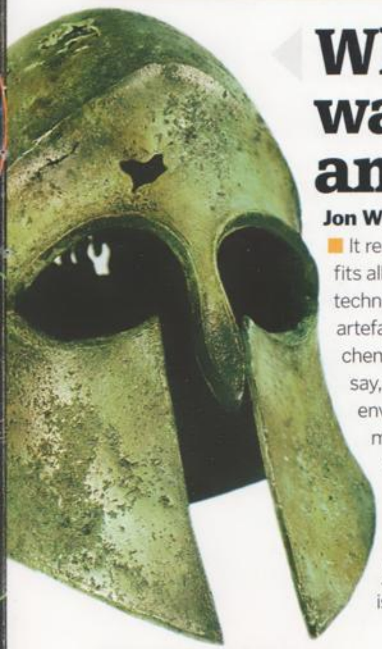
David Gelsthorpe

How can we age metal items?

Mac Naylor

There isn't an intrinsic method of dating metal as there is for wooden objects such as radiocarbon-dating or tree-ring dating. Much depends on the assessment of the object. For instance, an axehead made of bronze is likely to date from the Bronze Age, before knowledge of how to make iron. The date of the discovery of metal-working is going to vary in different parts of the world, but in Britain it will be towards the end of the third millennium BCE – roughly 2300-2000 BCE. The method of working the metal is also a crucial factor for ageing. Casting of iron only became possible during the Industrial Revolution in north-west Europe, for example.

Bryan Sitch



What's the best way to preserve ancient artefacts?

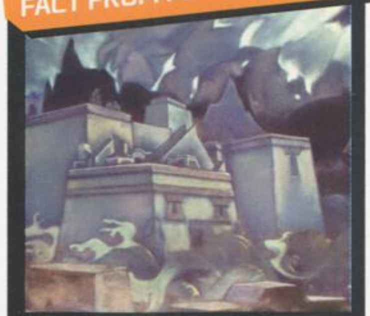
Jon Wardle

It really depends on what you've found. There is no 'one size fits all' answer. I'm sure any conservator would say the technique of preservation is dictated by the materials the artefacts are made from. Different materials have different chemical properties and characteristics. An object made of, say, iron might have to be cleaned and kept in a dry environment to prevent it from rusting. A bronze object too might need cleaning and keeping in a dry store to prevent bronze disease. A waterlogged wooden object could be treated by soaking it in water-soluble wax and then freeze-drying. It might be sufficient to clean and glue back together pieces of broken pottery, while gold jewellery might need no intervention at all because gold is an inert (or non-reactive) metal. **Bryan Sitch**

TRUE FALSE

MYTH BUSTER

SIFTING HISTORICAL FACT FROM FICTION



Did Atlantis really exist?

The story of Atlantis appears in accounts of two conversations between the Greek philosopher Socrates and his friends, Critias and Timaeus, written down by Plato over 2,000 years ago.

In the first account Atlantis was said to be a large island opposite the pillars of Hercules (the straits of Gibraltar). The king of Atlantis wanted to conquer lands around the Mediterranean but Athens resisted. The island of Atlantis and its people were later destroyed by the sea.

In another story the gods bring about the destruction of the island because of the arrogance of its inhabitants. The debate about whether Atlantis really existed has been going on ever since.

Some have claimed to have found ruins of sunken cities beneath the sea. One intriguing possibility is that the story of Atlantis is an account of the destruction of the island of Santorini in a volcanic eruption which is said to have brought Minoan power on Crete to an end. The story of Atlantis may simply be a warning about what happens to people who think themselves all powerful. Or it may be a half-remembered story about the eruption of Santorini. Whatever the case it has captured our imagination and it will continue to feature in films and books.

Bryan Sitch

Verdict:

☐ **True** ☑ **False**

MANCHESTER 1824

The University of Manchester
The Manchester Museum

What's on?

Unearthed: Ancient Egypt

WHAT: 100 years ago, many Egyptologists carried out huge digs in Egypt, unearthing ancient objects such as toys, farming tools, stone carvings and burial goods. These discoveries give us an idea of what life was like for the Ancient Egyptians, from their home life and work to their language and beliefs. Travel back to the 1920s and enter the storeroom of our Twenties Egyptologist, played on film by Terry Deary, author of *Horrible Histories* and *Egyptian Tales*.
WHERE: The Manchester Museum, Floor G Temp Exhibitions space
WHEN: Until 6 September 2012
PRICE: Free

The Museum Allotment

WHAT: See what's growing on our allotment. The allotment has been inspired by the Museum's new Living Worlds gallery which explores the connections between all living things, including us, and shows how we can all shape the future by the choices we make (such as growing our own food).
WHERE: Located outside The Manchester Museum
WHEN: Until autumn 2012
PRICE: Free

Living Worlds

WHAT: See natural history as you've never seen it before. Through displays designed with the help of fashion events company villa eugénie and an accompanying smartphone app, Living Worlds explores the connections between all living things and demonstrates how every one of us can shape the future by the choices that we make.
WHERE: The Manchester Museum, Floor 1
WHEN: Ongoing
PRICE: Free

Further information

For further information, visit the What's On section at www.manchester.ac.uk/museum.

Visit the Museum

The Manchester Museum, The University of Manchester, Oxford Road, Manchester, M13 9PL
0161 275 2648
museum@manchester.ac.uk

BRAIN DUMP

Because enquiring minds want to know...

Why are buses in London red?

Find out below

Want answers?

Send us your questions using one of the methods opposite and we'll get them answered

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HOW IT WORKS EXPERTS

london transport museum

Caroline Warhurst
Information services manager, London Transport Museum

Caroline is responsible for ensuring that the Library collection at the Museum is looked after and that all enquiries sent to the LTM are answered accurately. She also helps colleagues from Transport for London, designers and students with historical research.

What's on?

Sense and the City

WHAT: Love it or hate it, emerging technologies are transforming the way we live, work and play in our cities. London Transport Museum's special exhibition, Sense and the City: smart, connected and on the move, unravels the digital future, and compares this with past visions of the future. And a new poster display – Painting by Numbers – complements the exhibition by showing historical versions of data visualisation – infographic posters at their best.
WHERE: London Transport Museum
WHEN: The exhibition and the poster display close on 18 March 2012
PRICE: Adults: £13.50, Concessions: £10 – allows unlimited entry for a whole year, Children: Free

Film: Future Cities

WHAT: An eclectic selection of short films, animations and motion graphics that present evocative visions of future city living. Juxtaposing utopian fantasies against nightmarish dystopias, Future Cities highlights the obsession today's image-makers have with the possible metropolis of

What makes rubies red?

Find out on page 87

Why are London buses red?

Jane O'Connor

■ The iconic red London bus has a long history. In 1907 at a time when there was fierce competition for passengers, and route numbers had only just been introduced, operators still used a variety of colours to indicate where the bus was going. The largest operator, London General Omnibus Company, decided to make its buses stand out. It chose a spoked wheel as a symbol and the colour red for all its vehicles. When London Transport was eventually formed as a single company in 1933, red was already the predominant colour, so all buses in the Greater London area became red. **Caroline Warhurst**

When was the very first bus service in London?

Thomas Farrant

■ London's first regular bus service was started by George Shillibeer on 4 July 1829. He had seen the omnibus operating successfully in Paris and was inspired to do the same in London. Shillibeer's Omnibus carried up to 20 passengers and was drawn by three horses. There were no fixed bus stops as we know them today – passengers just hailed a bus from the roadside. To stop the bus, passengers either banged on the roof or pulled on reins attached to the driver's arms! Although called Omnibus (meaning 'for all') the fare of one shilling meant only the well-off could afford to use it. The first route ran from Paddington in west London via Regent's Park to Bank in the City. The eight-kilometre (five-mile) journey took about an hour. **Caroline Warhurst**

Who designed the B-type bus?

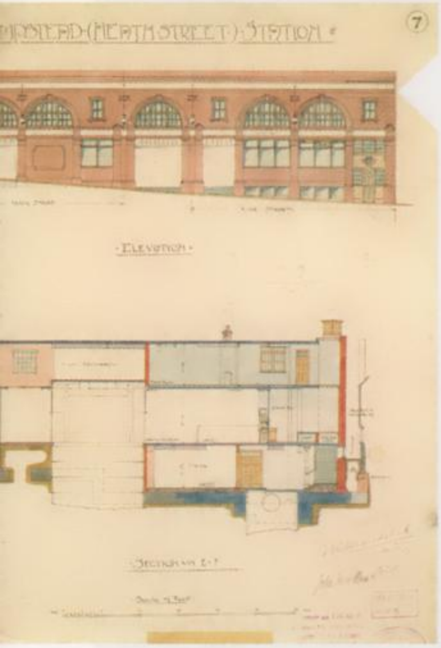
Rob Browne

■ Frank Searle joined the London General Omnibus Company (LGOC) in 1907 as chief engineer. He knew traffic conditions in London required a vehicle of rugged design and used knowledge gained through the development of experimental motor buses to produce the B-type in 1910 – the first reliable, mass-produced motor bus. The 34-seat double-decker was relatively quiet, easily maintained and became hugely successful. Although slow and open to the elements, millions of Londoners depended on it to get to work. In just a few years, by 1914, over 3,000 vehicles were in service – and London's last horse-powered bus was withdrawn. **Caroline Warhurst**

Tatcho
GENERAL

Where are the deepest London Underground station platforms?

Marc Compton-Bennett



At 58.5 metres (192 feet) the platforms at Hampstead station (opened 22 June 1907) are the deepest of all the London Underground stations. Hampstead also has the deepest lift shaft on the system at 55.2 metres (181 feet); that's just 1.2 metres (four feet) less than the height of Nelson's Column! On 11 April 1954, two new high-speed lifts, which travelled the 55-metre (181-foot) journey in 18 seconds (almost four times as fast as the 1907 lifts they replaced), came into service. They were then the fastest lifts anywhere in the UK.

Not surprisingly the station also has the longest spiral staircase on the system, with a total 310 steps. A notice advises passengers not to use them.

Caroline Warhurst

SHEPHERD'S BUSH & KEW BRIDGE.
PIANOS

Why weren't people electrocuted if they stepped on a tram track?

Maria Forrest

The supply of electricity to London trams was designed to be safe and prevent people getting hurt. One side of the supply was earthed, and the live supply was placed out of reach. In the overhead system the live wire was over six metres (20 feet) above the roadway. In the conduit system the live rail was buried in a channel in the road. Underneath the tram a 'plough' reached down into the conduit to connect with the electricity supply, which drove the tram.

Caroline Warhurst

INSTANT GENIUS

Brush up on your gems with the help of this issue's guest expert

The colour of this popular gem is a result of free electrons and light

THE EXPERT

WHO:
Brian Jackson

Brian is the principal research curator of Mineralogy at National Museums Scotland, chairman of the Scottish Gemmological Association and a board member of the Gemmological Association of Great Britain.

What gives rubies their distinctive red colouring?

Ruby is the red variety of the mineral corundum (Al2O3). In the structure of atoms which makes up a ruby, small amounts of chromium (normally about 1 per cent) can replace aluminium. In pure corundum, which is colourless, all the energy levels in the aluminium and oxygen are occupied by paired electrons. In chromium, however, six electrons are available for bonding but only three are required – this leaves partially filled energy levels. Electrons in these can absorb energy from visible light. The energy remaining corresponds to red light in the spectrum. Simultaneously ruby will absorb energy in the ultraviolet and re-emit it in the visible part of the spectrum as red light (ie fluorescence). The red colour is therefore ultimately caused by the presence of chromium.

london transport museum

tomorrow. The screening will be introduced by onedotzero and followed by a Q&A session with guest filmmakers.

WHERE:
London Transport Museum
WHEN: Wednesday 1 February 2012, 6.30-8pm
PRICE: Adults: £8, Concessions: £6 (discount for combined ticket to the Shock the System debate)

Debate: Shock the System

WHAT: Broadcaster and author Robert Elms chairs a public debate about the trade-off between the freedom new technologies bring us and the price we pay in terms of our privacy. Panel includes *London Evening Standard* comment editor, Andrew Neather, The London Mayor's director of digital, Kulveer Ranger and award-winning documentary filmmaker David Bond – creator of the chilling film *Erasing David*.
WHERE: London Transport Museum
WHEN: Wednesday 8 February 2012, 6.30-8pm
PRICE: Adults: £5, Concessions: £3 (discount for combined ticket to the Future Cities film night)

Artists' showcase: Play and the City

WHAT: Mobile devices and social media are having a dramatic impact on the way we use our city. Technology designed for navigation and communication purposes is being subverted by artists and gamers who seek alternative urban adventures. During the evening artists will share how mobile and social-networking tools can transform a city into an interactive playground. Play and the City is produced in partnership with digital arts organisation onedotzero.
WHERE: London Transport Museum
WHEN: Friday 16 March 2012, 6.30-8.30pm
PRICE: Adults: £9, Concessions: £7 (includes a complimentary drink)

Further information

Further information about events and exhibitions at www.ltmuseum.co.uk. To book in advance call 020 7565 7298.

Visit the Museum

London Transport Museum, Covent Garden Piazza, London, WC2E 7BB. Open daily. Adult admission charged and allows entry for a whole year.

THE KNOWLEDGE
GAMES · BOOKS · GADGETS · TOYS

For connoisseurs of kit and savants of stuff

Sennheiser HD 299 headphones

Price: £60/$80

Get it from: www.sennheiser.co.uk

These sleek and stylish headphones from Sennheiser offer exceptional audio quality at a reasonable price, with the almost unprecedented bass quality for low-cost headphones being their unique selling point. Also available in black, the headphones are very comfortable to wear and do an excellent job of blocking out external noise in addition to preventing noticeable noise bleed. Listening to any type of music through the HD 299s, from classical to drum 'n' bass, is a joy, as the sound quality is so crisp. These are a highly recommended purchase for anyone looking for a pair of top-quality headphones at a budget price.

Pros:
✓ Great audio quality

Cons:
☒ Comfortable to wear

MicroVision ShowWX+ Laser Pico Projector

Price: £300/$349

Get it from: www.microvision.com

If you've ever wanted a portable projector for your home cinema needs then this offering from MicroVision is the perfect way to go. This gadget simply blew us away with the quality and clarity of its images. Simply plug a device such as an iPhone or digital camera in and the Pico will project your video and images onto any flat surface. The design is slick and you'll get to grips with the functionality almost immediately. The 840 x 480 resolution is great and, while it's only really usable in low-light conditions, you'll be able to enjoy videos from your smaller devices on a much larger scale. Our only complaint was the two-hour battery life, which is enough to view most films but could be longer.

Pros:
✓ Excellent quality
✓ Easy to use

Cons:
☒ Limited battery

HOW IT WORKS EDITOR'S CHOICE AWARD

The Maths Handbook

Price: £7/$10

Get it from: www.quercusbooks.co.uk

This book from academic writer Dr Richard Elwes presents a variety of mathematical topics with simple text and informative pictures. It starts with the easiest of topics, which can seem tedious and are probably too basic for most. From addition and subtraction to understanding fractions, only those who really struggle with this subject will likely want to read the first half in any depth. However, Dr Elwes eventually begins to delve into topics that most will be unfamiliar with, from tackling logarithms to understanding Pythagoras's theorem. If you can get past the at times condescending opening as you are spoonfed how to add two plus two, you will eventually be rewarded with an informative and entertaining explanation of more complex areas of mathematics and algebra.

Pros:
✓ Excellent layout

Cons:
☒ Too easy in parts

DK Featuring new images fro
SPAC
from earth to the edge of the
SENNHEISER
MicroVision
The Maths Handbook
Everyday Maths Made Simple
360°
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Circumference
Richard Elwes
The Maths Handbook
Richard Elwes
Quercus

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HOW IT WORKS SUBS OFFER Flip to pg 92 for full details

DK Space

Price: £25/$40

Get it from: www.dk.com

'From Earth to the edge of the universe' is the tagline of this book, and you certainly won't be disappointed as Dorling Kindersley takes you on a journey from Earth orbit to distant galaxies. This fantastic book has over 300 pages of cosmic content, detailing through illustrations, photography and text how pretty much everything in the universe works. You'll find out what's at the heart of the Cat's Eye Nebula, discover the secrets of supergiants and learn about mankind's successful space exploration missions. You'd be foolish not to check out this book if you have even the faintest interest in astronomy.

Pros:
- ✓ Fascinating information
- ✓ Tons of content

Science Museum Space Origami

Price: £8/$12

Get it from: www.sciencemuseumshop.co.uk

If you've ever fancied creating space-themed origami then this little set will whet your whistle. However, it's no wonder it comes at such a low price as the contents are really just coloured sheets of paper and a small manual. That being said, the instructions are easy to follow (even if they are devoid of explanatory text) and you'll be able to create everything from spacemen to spacecraft with ease. It's a bit of a shame there aren't more things to make, and some extra colours or stickers would have been great to liven up the otherwise fairly bland paper structures. However, overall, this still makes an excellent little gift for craft and space lovers of all ages.

Pros:
- ✓ Simple instructions

Cons:
- ✗ Not much content

m NASA
univ
space origami
The folding frontier
Build seven different models, including a super nova star and a Lunar Excursion Module

Sculpted Eers PCS-200

Price: £192/$300

Get it from: www.sculptedeers.com

Ever find that earbud headphones like to jump out of your ears, or they just fail to block out external noise? Well, Sculpted Eers has developed a product that literally moulds itself to your ears. When you get the PCS-200 you put the buds into your ears with the included installation kit, which injects silicon into the buds so they mould to your ear canals; this takes about four minutes. Sound scary? It's not. The product is medically approved and we had absolutely no problems getting it to work. The results are awesome. You can hear absolutely zero external noise and though the sound quality wasn't top of the range, it'll be good enough for most. There's also a cheaper variant available, the PCS-100, at £130/$200.

Pros:
- ✓ No external noise

Cons:
- ✗ High price

APPS OF THE MONTH

Brought to you by **Apps Magazine**, your essential guide to the best iPhone and iPad apps available on the Apple App Store

iPad

7 Billion

Price: £2.99/$4.99
Developer: National Geographic Society
Version: 1.1 / Size: 324MB / Rated: 4+

Marking the 7-billion population milestone Earth passed last year, this app mixes the fantastically written articles from *National Geographic* with videos and infographics. The amount of content, focusing on what the increasing population could mean for our world, is incredible and presented beautifully.

Verdict: ★★★★★

Doctor Who Encyclopedia

Price: £6.99/$9.99
Developer: Random House Group
Version: 1.1 / Size: 257MB / Rated: 4+

This app gives users access to over 3,000 entries written by former *Who* script editor Gary Russell. It has been adapted from the recently released hardback version, and lends itself beautifully to the iPad. It packs in a lot of trivia including info on the home planets of baddies like the Daleks and Cybermen.

Verdict: ★★★★

iPhone

Tactical NAV

Price: £2.49/$3.99
Developer: AppDaddy Technologies
Version: 2.8 / Size: 6MB / Rated: 4+

Actually created and developed by troops, this app allows you to plot various locations and share them to allow for quick and clear navigation or target designation. The app uses the military grid reference system and has a built-in compass, in addition to allowing you to tag locations and add photos in order to covertly share further details about a location.

Verdict: ★★★★★

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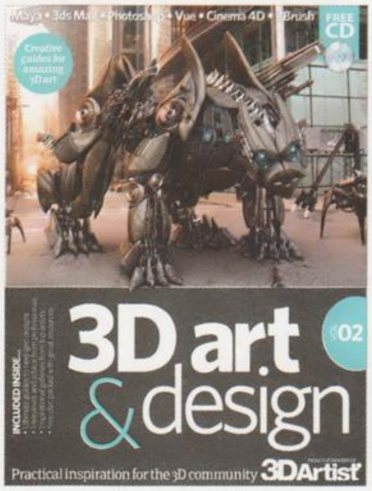
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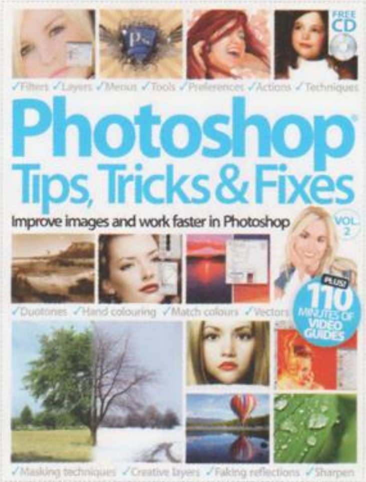
Practical inspiration for the 3D community
3DArtist

3D Art & Design vol 2
Covering all the major players in the 3D design world including Maya, 3ds Max, Vue and ZBrush, this in-depth guide will help you create 3D art like never before.
SRP: £14.99

Your creative guide to understanding Photoshop
FREE CD
Volume three
Beginner's Photoshop
PLUS! 147 MINUTES OF VIDEO TUTORIALS
The easy way to getting started with Adobe Photoshop
Learn how to edit photos, make digital art and more
256 pages of guides, tutorials and features inside

Beginner's Photoshop vol 3
This third volume covers over 50 new inspirational Photoshop projects in an easy-to-follow format complete with over an hour of video tutorials on the disc.
SRP: £12.99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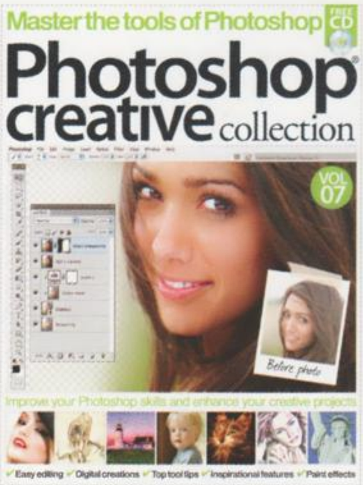
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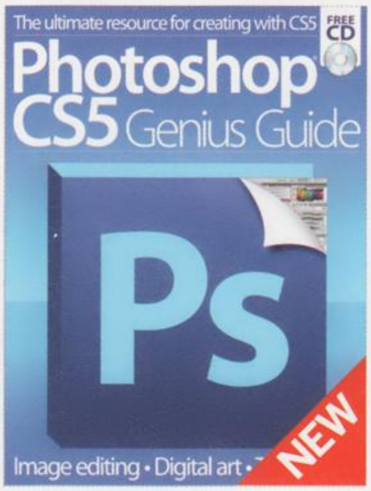
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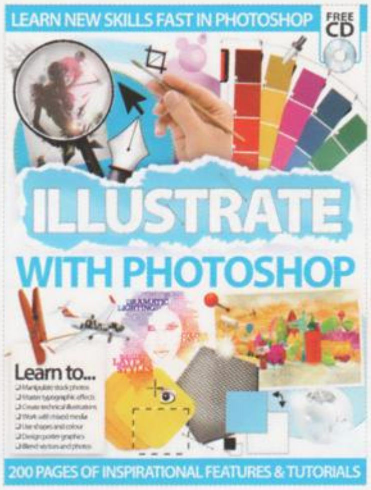
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Tablet PCs

We put three of the latest tablets to the test

HOW IT WORKS
EDITOR'S CHOICE AWARD

Andy Pad Pro

Pros:
- ✓ Low price
- ✓ Impressive functionality

Cons:
- ☒ Poor cameras

Price: £179/$279

Get it from: www.andypad.co.uk

Though it may eschew some of the more nifty features of its competitors, the Andy Pad Pro is a budget tablet that still packs a formidable punch as an excellent low-cost alternative. Unusually for such a reasonable tablet it has a seven-inch capacitive touchscreen, allowing for great usability. It also boasts an impressive 16GB of internal storage and a microSD slot for extra memory, which is very welcome. Unfortunately, the 1GHz processor does struggle occasionally and you won't get the same responsiveness as the Transformer or the Galaxy Tab 10.1. It also has front- and rear-facing cameras but, although the latter can produce 2MP images compared to 0.3MP for the former, neither is exceptional. However, its sturdy design ensures this is the perfect tablet for younger kids, commuters or those just shopping for a bargain. It might have a few flaws but considering the low price it's being sold for we can forgive it these. You can also pick up the slightly cheaper non-Pro Andy Pad, which has 8GB less memory but is a super-cheap £129 ($200).

Verdict: ●●●

Asus Eee Pad Transformer

Pros:
- ✓ Snap-on keyboard
- ✓ Extended battery life

Cons:
- ☒ Fingerprints on screen

Price: £380/$429

Get it from: www.asus.com

The Asus Transformer is immediately noticeable for one defining feature: its snap-on keyboard. While the tablet itself can operate as a standalone Android tablet, it can be plugged in to the attachment for full keyboard functionality, transforming (ahem) the device into a laptop. Although the keyboard will set you back an extra £50 ($75), we think it's well worth the cost, especially considering the dock also acts as an additional battery, giving you a total of 16 hours. Two models of the 10.1-inch tablet are available – 16 and 32GB – with the latter costing a bit extra. The tablet itself is fast, smooth and incredibly responsive. The dual-core processor is brilliant, rivalling most other tablets on the market for performance. The build quality of both the dock and the tablet are also top-notch, with our only gripe being the showing up of fingerprints on the screen. There's no doubt this device surpasses other tablets even without the keyboard, making it a worthy winner of our group test. Asus is also due to roll out the more powerful Transformer Prime, which packs a quad-core processor.

Verdict: ●●●●●

Samsung Galaxy Tab 10.1

Pros:
- ✓ Lightning fast
- ✓ Very thin

Cons:
- ☒ Wi-Fi only

Price: £400/$500

Get it from: www.samsung.com

Samsung's Galaxy Tab 10.1 is one of the best Android tablets on the market, boasting impressive processing speeds and a nice clean build to provide a well-rounded experience. As you might have guessed the screen measures an impressive 10.1 inches, and the clarity of the 1,280 x 800 display is brilliant. The dual-core CPU ensures the device is fast, loading apps and webpages in seconds. It's incredibly thin, just under nine millimetres (0.4 inches) thick and weighs about 0.5 kilograms (one pound), but the build quality isn't the best, with the back having a rather plasticky feel. Another niggle is the camera capability. While it's great that front and back cameras have been included, the low megapixel counts mean you won't be taking high-quality pics and video, although for video calling they more than suffice. 3G support is currently non-existent, leaving the device Wi-Fi only, but on the plus side there are 16, 32 and 64GB user memory models available. All in all, with up to 11 hours of battery life and an impressive all-round performance, this is truly a tablet to be reckoned with.

Verdict: ●●●●

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HOME EXPERIMENT

Make a spectroscope

SPECTROMETE

Split light into its constituent colours and learn about atoms with this easy-to-make gadget

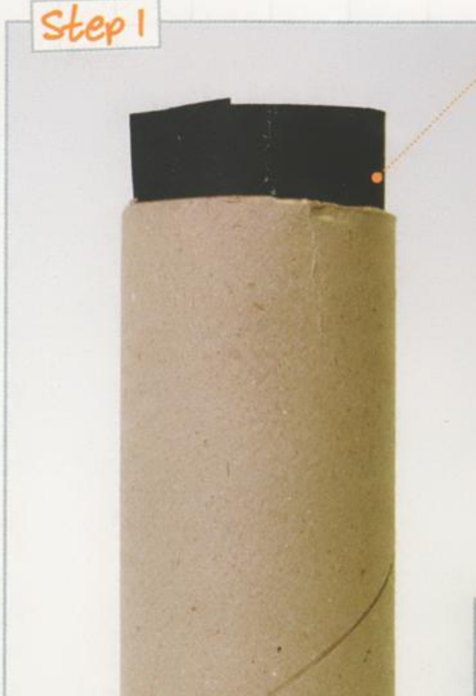
Spectrography is an incredibly useful process for scientists and astronomers, which enables them to investigate the chemicals found in objects located trillions of miles from our planet. This is because the atoms of different elements – which in various combinations make up every part of the universe – have their own distinct patterns, and by observing these patterns scientists can determine what an object, such as a star, is made of.

Spectrography is not all about observing space, however; it also has numerous applications in the laboratory here on Earth, or indeed your very own home for educational purposes. By following these five simple steps, you too can investigate light and study it on an atomic level with your very own spectroscope.

Equipment:

1 x kitchen roll tube
2 x A4 black card
1 x transparent CD
Packing tape
Pencil
Glue
Scissors

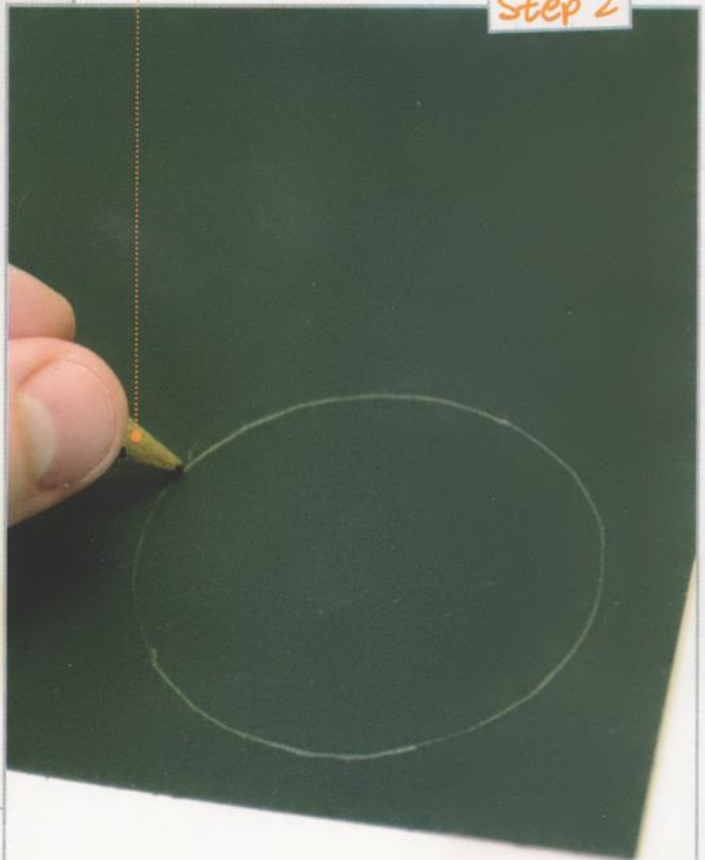
Step 1



Step 1. Okay, first take your kitchen roll tube and insert the black card so that it lines the interior wall. When you have a tight fit, carefully pull out the card and tape it at the desired point, before cutting off any excess at either end. Once the black card is a single tube, slot it back inside. If you have done this correctly, the black card should hug the kitchen roll tube's wall snugly.

Step 2. Next, take the remaining piece of black card and place the kitchen roll tube upright on top of it. Draw around it with your pencil and then remove the tube. Cut roughly around the outer circumference, ensuring that you leave a centimetre overrun at all points (ie the cut-out circle is a centimetre wider than the tube's circumference).

Step 2



GET IN TOUCH!

If you have a go at our experiment either at home or at school, remember to send us some pics to howitworks@imagine-publishing.co.uk so we can see how you got on.

HOME EXPERIMENT
MAKE A SPECTROSCOPE

DISCLAIMER
Under no circumstances use your spectroscope to look at the Sun or an artificial light source for a prolonged period of time. Further, when using your spectrometer, never look through it with either of your eyes pressed to the viewing screen – instead always observe from a minimum distance of 15 centimetres (six inches). Finally, in following this guide, you agree that neither Imagine Publishing nor any of its employees are in any way liable for potential injury or unwanted side effects to your person.

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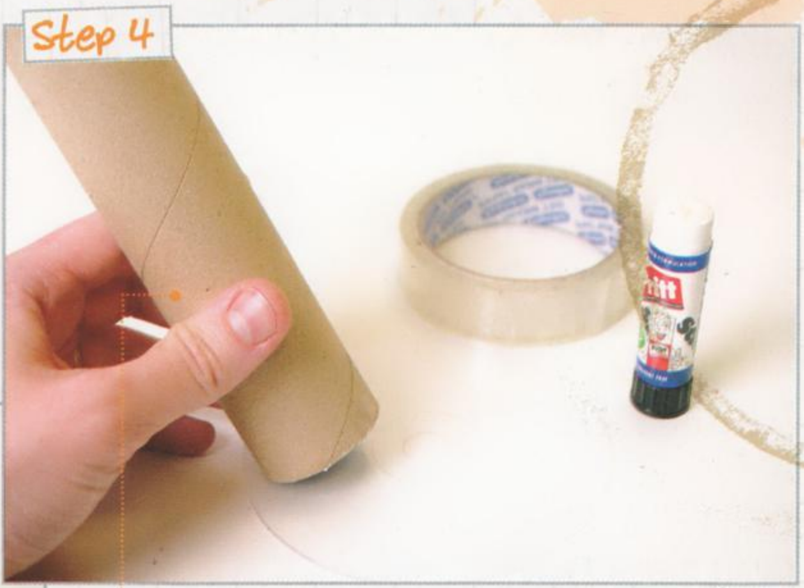
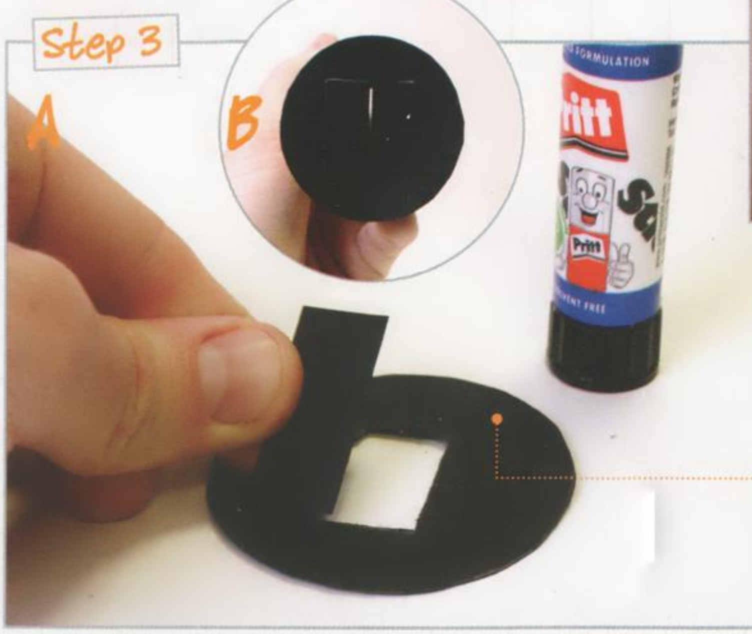
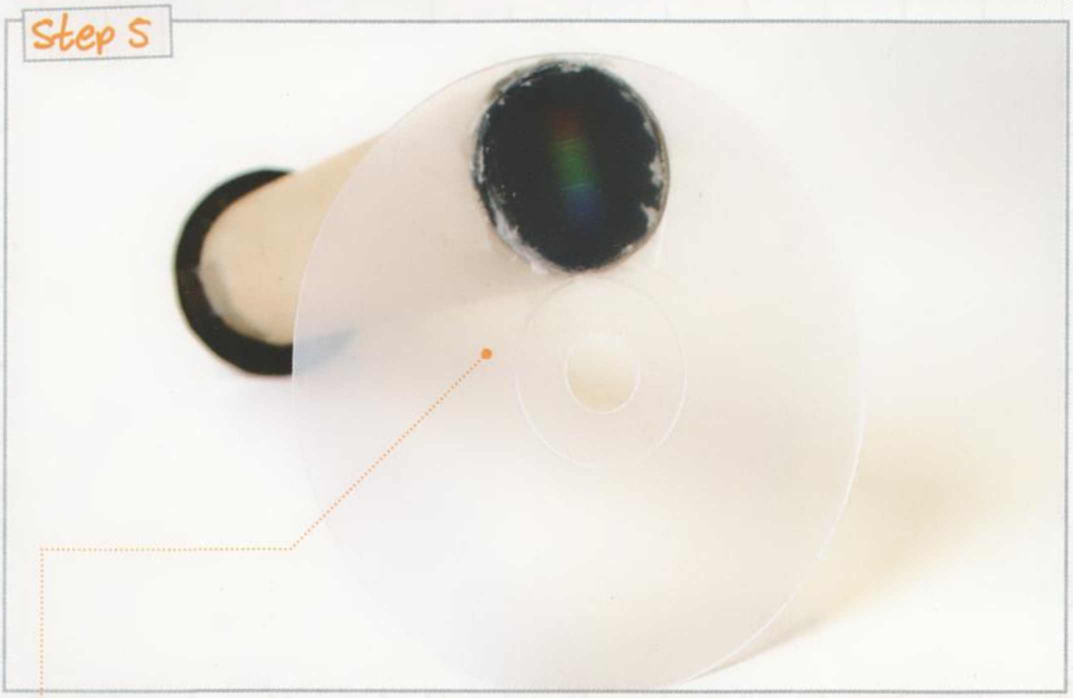




Step 4. If you have followed the previous steps closely you should now have something like this. If so, take your CD and stick it onto the other end of the kitchen roll tube. Importantly though, do not stick it in the centre of the disc; instead stick it over one of the transparent edges. You want to be able to look through the CD into the tube. Above you can see the ideal setup.

Step 3. Once you have your circle of card, cut out a rectangle in the middle then stick it to one end of the kitchen roll tube. Next, taking the remaining card, cut two smaller rectangles and tape them either side of the central rectangle so that only a narrow slit is left open. It's very important that the final slit is straight and level at either side (as per the image).



Step 5. Finally, after checking everything is secure and that there are no gaps in your spectroscope, hold it up to a bright light source – such as a light bulb – while looking through the CD end of the tube; do not put your eye directly to the CD, but rather stand off by at least 15 centimetres (six inches). If you have made the scope as instructed, a colourful, rainbow-like spectrum should appear on the transparent surface of the disc. This works especially well if you cover one of your eyes.

Stop! Science time!

So what is happening and how does this work? The spectroscope is splitting the light into its constituent colours, which are determined on an atomic level. The CD screen acts as a diffraction grating, bending light as it passes through, filtering the wavelengths of the white light (white light is a mixture of all wavelengths) in the process. This is why a rainbow-like array of colours is presented to the human eye. As such, each time you look through the spectroscope at a different light source, the spectrum of colours will vary, determined by the wavelengths it is emitting. Test it out on a few different lights!

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HOW IT WORKS

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Get in touch!

We enjoy reading your comments every month. So keep us entertained by sending in your questions for the mag, comments on what you like/don't like, any science-related news you want to share, or just say hello…

Win!
Hexbug robotic toy

Is the bull shark the most dangerous of them all?

Letter of the Month

Shark attack

I would disagree with your assertion that the great white is the most dangerous shark in the world in issue 26. While the great white is a dangerous animal and is the largest non-filter-feeding kind of shark it is by no means the most hostile.

The bull shark is easily the most aggressive of all sharks, often attacking merely as a result of having a bad-tempered nature. Its ability to withstand even only mildly brackish water means that many casualties have occurred when people have been swimming, washing their clothes or fishing, even far upriver. Most shark 'attacks', including those by great whites, start as inquisitive bites just to suss out what is in front of them. Only if blood is drawn does the natural arousal of senses cause the feeding instinct to kick in.

I would put the great white in third place after the tiger shark mainly because these animals feed as pack hunters and work together to achieve a kill, while the great white works alone. The white tip reef shark is another variety to be wary of, unlike its cousin the black tip, which I have swam with happily on a number of occasions with no fear.

Richard

HIW: Fascinating stuff, Richard, thanks for getting in touch. Your excellent knowledge of sharks has earned you Letter of the Month – and we're happy to report Hexbugs are totally safe!

LETTER OF THE MONTH COMPETITION

WIN FIVE HEXBUGS!

We've partnered with Hexbug to bring you the hottest toy of the moment. One lucky reader's letter each month will win five Hexbug Nanos. These small robots will scurry around any flat surface and they'll even work around obstacles.

Nice to meet me

The article on mirrors reminded me… recently I was working in a building that had lifts with mirrors covering the walls inside. If you stood and looked at your reflection in the mirror on one of the walls, then held out your hand as if you were going to shake hands, your reflection held out the wrong hand so you couldn't shake hands with it. However, if you looked at your reflection in the corner of the lift, where two mirrors joined, and did the same thing, your reflection held out the correct hand to shake. By the way, the magazine is excellent – it just keeps getting better and better. My son, wife and I all read it – keep up the good work!

Andy

Laser speed

I was reading an article on the internet a few days ago and it said that you could break the speed of light in your garden. All you needed was a laser pointer and a clear night sky. It said that all you needed to do was point the laser at the moon and flick your wrist. The laser dot that you see on the moon would then be moving faster than the speed of light because the moon is so far away. That then got me thinking, if we can do this with a laser, then theoretically couldn't we do this with a person? All we would need to do is make a HUGE and very strong metal rod that was as long as the distance from Earth to the moon, then we would attach a capsule to the end of it with a person inside and suspend the capsule in space. If we then held on to the end of the metal rod and flicked our wrist, then wouldn't the capsule and the person inside be moving faster than the speed of light? Although this idea is very ridiculous and highly theoretical, would it work?

Tom Wagstaffe (age 14)

HIW: We're not sure who your source is, Tom, but we're afraid they're way wide of the mark… The speed at which the light beam on the moon, or your capsule at the end of the rod, would propagate (move) would only be equal to the speed at which your hand initially moved. Unfortunately, unless you've found a way to move your hand faster than the speed of light (and if you have, get in touch with CERN quickly!) then this is simply impossible. Interesting suggestion though.

Up to speed

I know this is probably more of a general complaint as opposed to a question, but I was wondering what 'superfast broadband' actually means technically. All the internet providers are constantly telling us that they are rolling out superfast broadband through Britain, but they never tell you what that is. Is there a definitive technical benchmark that a connection must pass to be referred to as superfast? Thanks.

Paul Hart

HIW: Great question, Paul, now you might think it's just marketing spiel, but according to communications regulator Ofcom there is actually an official definition for the term 'superfast broadband'. It's defined as being a broadband product with a maximum download speed that is greater than 24mbps.

What would happen if you fired a laser at the moon?

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Lunar learned

I'm a reader from Australia and I got to witness 10 December's total lunar eclipse with my own eyes. After reading the information in How It Works (issue 28), I was able to explain to my friends just what was going on as no one really knew. It was a great moment – I'd never seen it before, and to make it even more memorable it was also my birthday. I'm so glad that there's a magazine like this that helps us to understand these amazing things that take place.

Katy Kennedy

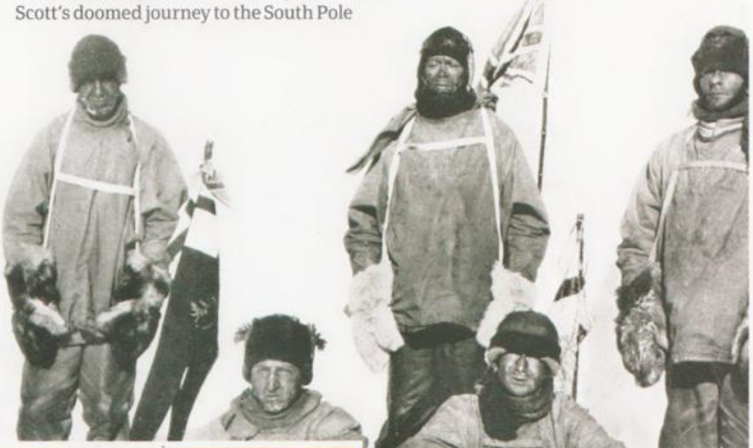
Great expeditions

My favourite section in the magazine is History. I saw in the last issue that it's 100 years since Robert Falcon Scott's expedition to the Antarctic. Will you be covering this in depth in the magazine at all? I'd love to read all about how the Terra Nova party set out to reach the South Pole as well as what it would have felt like, the obstacles they would have had to face along the way and, ultimately, how they perished.

Dean Wilson

HIW: 2012 is certainly going to be a big year when it comes to anniversaries, with the Titanic, Scott and Turing all featuring. We'll do our level best to fit all of them into the magazine, Dean.

2012 marks the 100th anniversary of Robert Scott's doomed journey to the South Pole



Growing plants on Mars is probably a nonstarter

Sowing the seeds

What a fantastic magazine. I look forward to every issue with its wealth of articles written in a very easy-to-understand style. I am starting a science course in the new year so the knowledge gained from How It Works will come in handy. The question I would like to ask is: would it be possible to send a capsule to Mars that would break open containing all types of seeds, and fling them over a wide area in the hope that they would grow? Could it cause any harm?

John Reynolds

HIW: Unfortunately, it's probably just the stuff of science fiction. Most seeds require water to grow, but the surface of Mars is too hostile for water to stay in liquid form. It either evaporates or freezes underground, which would leave the seeds without nourishment and unable to grow, causing them to swiftly perish. It probably wouldn't cause any harm to try, although there is a risk of contamination. In fact, all spacecraft intending to land on Mars have to adhere to strict contamination rules, and they must be built in a clean environment so they don't take any Earth bacteria to the Red Planet that could one day be mistaken for signs of native Martian life.

ConCERNed

I've been reading a lot about Higgs boson recently in the press and was wondering whether you think it actually exists or not. If so, will it really change physics all that much? Plus, what happens if the scientists at CERN prove that it doesn't exist? Surely that will cause more of a stir in the field of physics than if it was found to be real.

Tim Green

HIW: It's a tricky one, Tim, but all signs are pointing to its discovery at some point. However, many physicists are actually hoping it isn't discovered, so that some more antiquated areas of modern physics can be updated with newer theories. We'll have to wait and see.

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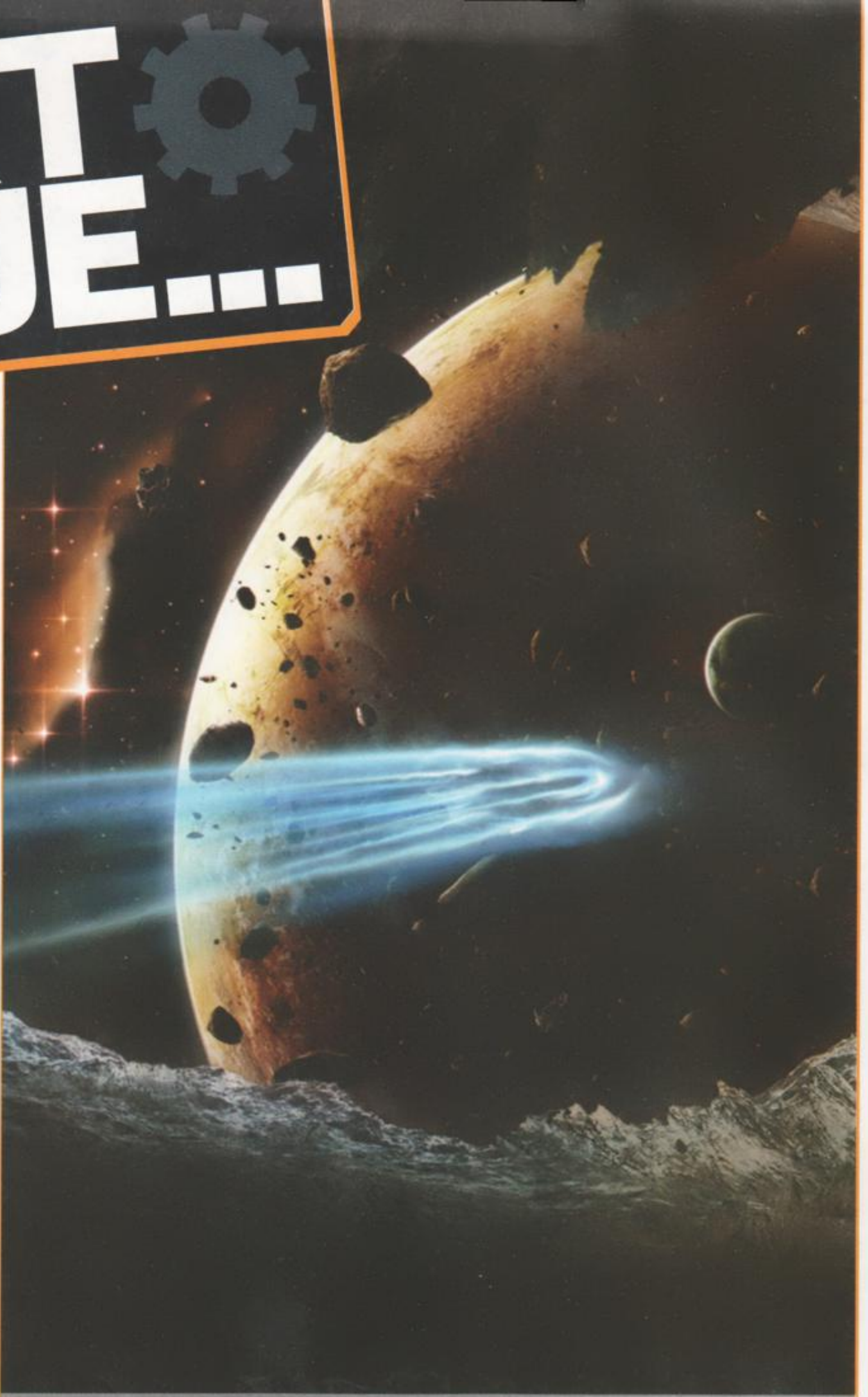

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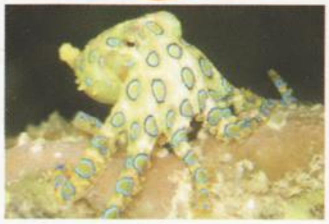

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